THE COST OF MINING

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THE COST OF MINING

A DISCUSSION OF THE PRODUCTION OF MINERALS WITH REMARKS ON THE GEOLOGIC, SOCIAL AND ECONOMIC FOUNDATIONS UPON WHICH IT RESTS

BY

JAMES RALPH FINLAY

PAST SECRETARY AND PRESIDENT MINING AND METALLURGICAL SOCIETY OF AMERICA; MEMBER AMERICAN INSTITUTE OF MINING AND METALLURGICAL ENGINEERS; LECTURER AT HARVARD AND OTHER UNIVERSITIES ON THE ECONOMICS OF MINING, CONSULTING ENGINEER UNITED STATES BUREAU OF MINES, ETC.

THIRD EDITION

ENTIRELY REVISED, ENLARGED AND RESET

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PREFACE TO THIRD EDITION

During the long and various delays that occurred while the revision of this book was taking its present form the question was entertained whether it would not be fairer to author and readers to give it a different name altogether. It will be seen that it is no longer so narrowly technical as it originally was.

But the question was answered in the negative. While it is true that some of the suggestions might, if properly presented, interest the public at large it seems at least as logical to believe that anything that will affect the mining public will affect the whole public. The gist of this idea is contained in a beginning at the revision made in 1917:

"There are in the United States alone some two to three million men engaged in the mining and metallurgical industries. With their families and those who are engaged in supplying them with living necessities, that is to say, with the merchants, professional men, educators, etc. who are employed in mining communities, we may count on not less than twelve to fifteen million people who are dependent upon and therefore interested in those industries. This is twelve to fifteen per cent. of the total population. If we apply this proportion to the whole English-speaking world, as we may fairly do, we find that at least 20,000-000 people are directly interested in mining and its cognate arts. When we consider that this number equals the white population of the British Empire of a century ago, it becomes evident that they make a field for literary effort larger, taking into account the growth of wealth and information, than that whole Empire could furnish at the end of the Napoleonic wars."

This paragraph will illustrate the growth of the conviction that such a body must act upon public opinion, whether consciously or not, as inevitably as the forces of nature.

It is therefore sufficient to ask indulgence of the mining public alone for interjecting among the obscure, sometimes trivial figures of mining operations certain suggestions of broader scope. I may quote again conveniently from the earlier paper:

"It is necessary also to dwell upon the development of the human animal, intellectual, social and economic, which must take place in order to bring this industry into existence. Let us recall the obvious fact that to the Algonquin Indians who lived in Pennsylvania three centuries ago the anthracite coal fields were not worth the hide of a single deer, and to those same Algonquins the Calumet and Hecla was not as valuable as a boulder of float copper. Then there is the history of these developments. How and why did great mining districts come into the possession of those who now own them and work in them? How do these owners and workers live and what is their outlook upon the rest of the world?"

At the risk of making a still greater hodge-podge I have ventured to insert some generalizations on geologic history and processes such as seem to explain the origin and govern the distribution of important minerals.

These new suggestions have come from a list of persons and experiences too long to enumerate. To the members of the Mining and Metallurgical Society of America and of the American Institute of Mining and Metallurgical Engineers; to many members and officials of the U. S. Geological Survey, U. S. Bureau of Mines and the Pan-American Congress; to many managers, lawyers and financiers; and, not least, to many employes and workers in mines I offer the impression they have made upon me.

Much of the statistical matter has been prepared and edited by Mr. G. A. Roush, editor of "Mineral Industry."

J. R. Finlay

Quogue, Long Island
Sept. 12, 1920.

PREFACE TO FIRST EDITION

This book is the result of experience in the mining business covering some twenty years, in the earlier of which I had to do in rapid succession with such diverse operating conditions as those presented by Lake Superior iron mines, gold mining in Ecuador and Colorado, and lead mining in Idaho and Missouri. The profound differences in methods imposed by natural conditions could not fail to impress themselves on one's attention.

Some six years ago a discussion started by Messrs. T. A. Rickard and W. R. Ingalls of the *Engineering and Mining Journal* on the "Cost of Mining" attracted considerable discussion from mining engineers throughout the world, and I contributed some articles. It was natural to continue the investigation of the subject. In 1908, at the suggestion of Mr. Ingalls, I undertook to prepare some more extended articles for the same journal with a view of rationalizing the subject to show how the natural factors inevitably impose certain costs that sound engineering must recognize, and that to attempt economies unjustified by the conditions is the rankest extravagance.

This book is the outgrowth of those articles and to a lesser extent of some lectures given at Harvard University and a large amount of discussion and correspondence. The subject is one that is inherently interesting to mining men and mining engineers and it seems possible that it may interest a somewhat wider field. Those who are interested in financial and economic developments can hardly escape some contact with the mining business.

A full treatment of the subject would be encyclopedic, but no attempt is made here to give the work that character. I have merely tried to give a certain perspective of the business in coal, iron, lead, zinc, copper, gold, and silver, concentrating my effort largely on an attempt to exhibit facts in their proper proportion. The principal source of facts is the official reports of mining companies which are not in some fields so numerous as could be wished, and, in fact, from some districts are not to be had at all. The best and most numerous reports are issued by copper, lead, and gold mining companies.

In the coal business, reports of a certain kind are abundant and generalized statistics are exceedingly abundant, but little is to be had in the way of detailed information necessary to a satisfactory cost analysis. Consequently, the chapters on coal mining are more general than those on other subjects; but while a detailed treatment of this immense busi-

ness would require a volume in itself, it may be remarked that coal mining is the simplest form of the industry and a sketch of its essential features does not need to be a long one.

A single corporation accounts for 55 per cent. of the iron output of the United States, and at the same time its reports are far more luminous than those of any other concern in this business. Accordingly much attention is given to the results and statistical history of the United States Steel Corporation. The independent companies are either utterly secretive or give only financial statements that do not yield much to analysis.

The discussion of lead mining covers the results obtained by companies typical of the conditions under which 80 per cent. of the American product is secured.

In zinc mining information is not very satisfactory, but it is possible to give some idea of the operating conditions under which some 80 per cent. of the American product is obtained.

In copper mining a great deal of detailed information is to be had showing results in a fairly satisfactory way in districts that produce nearly 90 per cent. of the North American copper. A few examples are taken from the outside world.

In gold and silver, the United States is not pre-eminent and examples are taken rather freely from all parts of the world.

It will be seen that the work deals largely with results; matters of an engineering or technical nature are generally left out even to the extent of ignoring such matters as the assay values of ores. This is done in order to make the conclusions base themselves on strictly practical and conservative grounds. It happens by way of coincidence that this volume will serve as a kind of supplement to Mr. H. C. Hoover's work on the "Principles of Mining," which deals with the processes of valuation, organization, and administration, and the methods used in mining the more precious metals. The reader will find in Mr. Hoover's book an outline of some of the technical problems not dealt with here.

I must acknowledge the assistance given by various friends in the preparation of this work. Professor H. L. Smyth of Harvard University in particular has aided with many important suggestions and is responsible for portions of Chapters I and II. Mr. W. R. Ingalls, editor of the *Engineering and Mining Journal*, has kindly allowed me to republish from the "Mineral Industry" of 1908 his important study of the cost of "Silver-Lead Smelting," which forms the whole of Chapter XVI. Mr. Raphael Welles Pumpelly has given great assistance in looking over many reports. Messrs. F. W. Bradley, T. A. Rickard, J. Parke Channing, Dr. Douglas, Courtlandt E. Palmer, H. M. Chance, George S. Rice, and many others have all contributed from time to time valuable suggestions and criticisms.

I cannot help feeling that, while all of the material in this book is either old or public property to the extent of being known to at least a portion of the profession, there is nevertheless something new in it in that it presents a view of the economics of mining on a grand scale and in broad outline. It does not seem possible that a mining man can fail to understand my meaning. If the facts are right the book is right. But in the great range of facts that I have tried to look into many things are more or less obscure and it is difficult to be sure that my information is authoritative. I shall be greatly obliged if the readers of this book will point out errors or supply information. If there is any demand for it I shall be glad to prepare a revised edition later, filling in some of the shortcomings of the present one.

J. R. FINLAY.

NEW YORK, *September*, 1909.

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THE COST OF MINING

CHAPTER I

THE SOURCE OF POWER

THE ECONOMIC FUNCTION OF MINERALS—MECHANICAL POWER REQUIRES ORGANIZATION FOR ITS UTILIZATION—ILLUSTRATIONS FROM THE EXPERIENCE OF THE GREAT WAR—IMPOSSIBILITY OF INDUSTRIAL NATIONS RETURNING TO THEIR FORMER CONDITION AND IDEAS—INDUSTRIAL POWER IS TRANSMUTABLE INTO MILITARY POWER—ECONOMIC PREPONDERANCES IN THE ANGLO-SAXONS

The Source of Power.—The value of minerals comes largely from the production of mechanical power. The energy lies in coal and chemicals; the application of that energy is obtained through the use of metals. Thus practically all mining contributes to the same ultimate purpose. The usefulness of power in ministering to human needs and desires makes it the most potent form of wealth; and its utilization is the essence of that civilization which we term "modern."

The traditional objects of mining enterprise that are celebrated in history and romantic literature, gold, silver and precious stones, seem to be an exception to this generalization; if so, they are merely an exception that proves the rule and an illustration of the new elements that have been brought into human life. These materials are either ornaments, a form of the wealth that may be obtained through the possession of power, or they serve, when used as money, as a kind of lubricant in the engine of production and thus after all participate in its functions. Thus mining may reasonably be described as the basis of the modern economic structure and this has long been evident to those who have given the matter attention; but it is to be doubted whether the great public in the world at large has ever given this fact and its possible consequences the attention that it really demands. The World War which has just been brought to a close has done more to arouse a public perception of the political and social implications that lie in the possession of mineral resources and the art of utilizing them than the sum total of really more important but less spectacular events that have gone before. This perception is not improbably the major development of this great political upheaval and it may have a decided influence on the mining industry for the future.

The manner in which the utilization of the powers that lie in the crust of the earth affects the social and political organization of mankind is indicated by some extracts from an address on "Industrial Energy as a Military Weapon" given before the Mining and Metallurgical Society of America in 1915. Although most of the factors dwelt upon in these

paragraphs are infinitely better understood now than they were when the article was written, the essential considerations will probably be brought out more vividly by quoting part of this address than by any new discussion that I might now write.

"At the beginning of the war I believed that industrial energy would prove to be the decisive factor in the struggle, and that this energy might be fairly represented by the use and production of coal and steel. Part of this proposition is now recognized by the public; the other part is not. It is now seen that the nations of Continental Europe that are facing Germany, namely, France, Russia, and Italy, are no match for Germany in the production of the necessary equipment and munitions for fighting. I argue that it is equally probable that the whole combination of the Allies, including England, is deficient in the capacity for organizing and for utilizing equipment. I am disposed to believe that the second element is more important than the first, because it requires time to develop. This proposition is based on the supposition that military success arises from the same kind of development as industrial success. It will take some time longer to prove this.

"The idea is abroad that Germany may be conquered by the Allies if the latter will buy enough copper and other munitions. The reality is that the buying of supplies is a comparatively insignificant part of the problem. To take an industrial comparison, let us suppose that the plants of the United States Steel Corporation were supplied, complete, to Russia, without the organization as it exists today. What use could Russia make of them?

"I do not mean to imply that the individual Russian is necessarily inferior as a workman, or as a man, to the individual American. That is one of the difficulties in understanding this present situation. Each of the great nations and races of mankind is able to furnish human material that can compete on even terms with that of any other nation. But I think you will recognize quickly that it would take the Russians many years to make any adequate use of the plants of the United States Steel Corporation. It is hardly worth while to go into details. The operation of those plants, including mines, steamships, railroads, rolling mills, and factories of all kinds, requires the development of a vast amount of specialized labor; it also requires a great deal more than that, namely, a slowly developed and highly organized control. The plans and the execution of them must be tested by competition with rivals. The organization must know the fields in which the products, when made, can be sold and utilized. It would be easy to dwell on this subject a long time, but I think you will soon conclude that the plants of the United States Steel Corporation would never reach anything like the effectiveness in Russia which they have in this country, until the Russian nation is developed industrially to such an extent that it can meet such an organization on even terms. In other words, other industries, all of the industries in the country, in fact, would have to be developed in a substantially equivalent manner. This certainly cannot be accomplished over night, nor during the probable continuance of any war. It is a matter that requires nothing short of the industrial organization and development of the nation. A generation, or even two generations, is a short time for such an accomplishment.

"Dropping this subject for a moment, it seems to me that we should discuss fundamentals a little.

"One such fundamental is that our political ideas and most of our beliefs and prejudices date from the time when the steam engine was unknown. I believe that economic changes have taken place in the leading civilized nations without producing, as yet, the inevitable change in political and social ideas. We are facing facts which we do not recognize, or at least, which are not recognized by the public. We go through forms of thought and attach ourselves to certain prejudices that will not stand the analysis of modern actualities. Some of our political sentiments are like the buttons on a dress coat, which were put there originally to attach swords to, because gentlemen wore swords, and the dress coat is the coat of a gentleman; but there is no longer any actuality in the sword as a weapon, either social or military. The fact that we like to see buttons on a dress coat is a mere sentiment which does not change in the least the relative efficiency of the sword and its successor, the revolver.

"What changes of a political, social, and religious nature are to take place I do not know. One thing that the world is learning beyond doubt, is that individual effort, no matter how well developed the individual, is no longer a match for corporate effort. This is a lesson that the Frenchman and the Russian must be learning. We in the United States have learned it, but we hardly realize that we have learned it.

"Let me try to explain what I mean: There are certain efforts that cannot be accomplished by the individual, that require a combination of people such as was not contempleted at the time when our government was established. We can see plenty of examples in the mining industry, and plenty more in the railroad business. In fact, we all know that the business of our country in general has reached a point where the large corporation is absolutely indispensable. Consider, for instance, the Utah Copper Company. Nothing but failure of such an undertaking could possibly have rewarded the efforts of any man or any group of men in this country 100 years, or even 20 years, ago. Look at the organizations required to conduct the railroad business of this country. The railroads all started in a more or less individualistic manner. A little railroad was built from New York to Harlem; another from Harlem to Poughkeepsie; a third from Pouhgkeepsie to Albany; a dozen pieces of railroad were constructed to form a patchwork system of travel between New York and Chicago. The progress of our industry soon made it plain that such a system was absurdly less efficient than it might be; consequently these little roads were thrown into one system, and operated by one head, so that freight and passengers could be carried through with less expense and delay.

"My belief is that the fundamental desire of the human race is to secure greater economy in the production of the necessities and luxuries of life. Any political system or any social idea which interferes with that economy will go to the wall, will be defeated and discarded. The demand for efficiency will finally triumph over any *preconceived* prejudices regarding personal and political liberty.[1]

[1] This statement has been a great disappointment to many persons who have written to me about it, but perhaps they have not realized fully what was meant. Let me explain my point of view by an example. Schoolcraft, writing about the mining industry of Southeast Missouri in 1819, just 100 years ago, gives statistics about the number of men employed and the amount of lead they produced. Comparing this information with the statistics of the present day we find that in 1919 each man produces 200 pounds of lead per day against 20 in 1819; ten times as much.

"We were all born while a revolution was going on in human affairs, and we shall die before that revolution ends. This revolution is a fundamental accomplishment, such as the human race is not likely to repeat again for thousands

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The natural difficulties to be faced in the way of depth, water to be pumped, etc. are much greater now than they were then. The industrial changes (and their effect on social organization) that have brought about these results can hardly be illustrated better than by Schoolcraft's description of a smeltery. He gravely estimates its cost at $40! A modern smeltery in the same district costs not less than $1,000,000. The amount of capital required to enter the lead business as an independent operator in 1819 was such that any miner now working in the mines could afford it if he could transport his present resources back to that period. At that time there were scores, if not hundreds, of independent operators; now, with the immensely increased output, the number of operators has been reduced to four corporations. The liberty of private enterprise has disappeared. The population of the district has no opportunity to earn a livelihood in lead mining other than to work for these concerns. What curtailment of liberty could be more vital than this?

"If we are to consider this situation as a political and social matter we have to weigh two questions; (1) Is a return of the conditions which gave so much personal liberty in 1819 desirable? (2) Is it possible?

"As to the desirability of it we may point to the fact that the gross output in 1819 out of which the lead miner could pay himself and seek return on his capital was 20 pounds of lead. Today his wages, without any capital yield, him the equivalent of 70 pounds. By surrendering his liberty to be an operator, he acquires another kind of liberty—that of having more to live on; better food, better clothes, more enlightenment, greater freedom of travel, a wider range of experience. There is such a thing as blind worship of catchwords. The word liberty is often used as a kind of fetish and anyone who seems willing to curtail it is apt to be denounced as a malignant heretic. But we are actually surrounded by innumerable limitations of liberty and the whole process of organization, cooperation and law is one of defining and establishing them. The one great liberty which may be obtained from suffering such restraints is the escape from economic misery. Thus I doubt if the Missouri miner entertains any real desire to exchange his situation of today with that of a hundred years ago. If it came to that he would reach the practical matter of weighing the liberties he has gained against those he has lost; and, sentiments to the contrary notwithstanding, the value of those liberties is measured in plain dollars and cents, or in pounds of lead.

"(2) Whatever the desirability of the old conditions, a return to them is impossible. They do not exist.

"Thus I think we may discern that in many ways the great industrial forces that affect political and social conditions act like the forces of nature itself. He who embarks his capital in a stage coach to compete with railroads, believing that railroad corporations are an improper thing, is as sure to be hurt financially as he would be sure to be hurt physically if he stepped out of a sixth-story window believing that the law of gravity is an improper thing. It seems absurd to argue about such great forces as matters of right and wrong; he is right who understands them; he is wrong who does not understand them. I suppose we may, as an intellectual exercise, picture to ourselves a return to the economic conditions of a hundred years ago, but to picture it as something that people would consent to, seems a mere extravagance. It would involve the starvation, or at least the migration, of scores of millions of people, make the great cities of the world impossible, annihilate the conveniences that the most civilized people have grown to regard as necessities and alter profoundly the relative power and influence of nations.

of years. It is something that we are all familiar with, but which we do not think very much about. It is the conquest of natural energy by the human brain.

"One hundred and fifty years ago, men had no resources for accomplishing their work except the muscular power of men and animals, with a little crude development of wind and water power. Now we use our hands and our brains to direct forces scores of times more energetic. The result is prodigious and it is causing a complete rearrangement of our mode of life. It is causing us to look upon nature itself in a different way, and it is altering profoundly the relations between men and between nations.

"The source of this power at present is largely coal. The power of coal is developed through machines made of metals. This is not so much a chemical or material fact, as it is a human fact. The utilization of this power is made possible only by the development of human organizations to match it. A locomotive is no more the machine that accomplishes the work of a railroad than a statue is a living man. You cannot use a locomotive without a railroad, and you cannot have a railroad without work for it to do; you cannot have work for it without big industries. In short, you cannot have first-class mechanical service and efficiency except in a highly developed industrial nation. The mere existence of power-driven industry on a large scale proves in itself that a country which supports it possesses a different and more efficient organization than a country which does not support it.

"When I learned some years ago that it took 10 or 15 Hindoo coolies to accomplish the work of one of our miners in this country, I could not understand it. The difference seemed preposterously great. It was all the more extraordinary because it occurred in a mine just as thoroughly equipped with machinery as the mines of this country. The reasoning I have offered you is an attempt to explain it. Industrial efficiency cannot exist in a population that neither understands nor demands it.

"An adequate explanation must cover the improvements that are steadily made in our business. I know of mines in which each man is producing twice as much as he produced 10 years ago, without working any harder, and without any improvements in or additions to the machinery. I am satisfied that industrial efficiency means nothing less than national effort, produced by slow growth, by the habit of cooperation, and by a widespread recognition of the value of cooperation and belief in it.

"Thus we come to understand that, while it is as true as it ever was that the Frenchman or the Russian is just as good a man, as an individual, as the American or the German, the possibility is open that in an industrial sense the French nation or the Russian nation may not be one-quarter as efficient as the Americans or the Germans.

"It is a fact not generally recognized that today there are only three nations in which mechanical industry is widespread, namely, the United States, the British Empire, and Germany.[1] It is not fair, of course, to say that industry has not been developed in other countries, but these nations are so far ahead of any rivals that they are very distinctly in a class by themselves. These three nations produce about 86 per cent. of the coal of the world, and undoubtedly operate

[1] This meant the Teutonic group as it was in the war.

an equally large percentage of its machinery. It is a remarkable fact—it may be an accident, but still it is a fact that all of these nations are predominantly Teutonic. It may be an accident that this race of men happened to gain possession of the more important territories that contained coal; but whether an accident or not, it makes no difference as to the importance of the developments that have come from it. It happens that one of these nations is the most highly developed military nation in the world. The other two, while developed industrially quite as highly as Germany, happen to be about the least military nations of the world. In my judgment, the unmilitariness of England and the United States is due to one cause only, namely, their isolation, their freedom from enemies capable of easily attacking them. If these nations felt compelled to do so, they could develop enormous military powers; but we may also believe, from our available sources of reasoning, that the development of such military power will take a long time and can be accomplished only by a thorough political and social organization on terms of military efficiency."

The statistics upon which these remarks were based are no longer of sufficient interest to be quoted in full. The essence of them was that after their occupation of Belgium and Northern France the Germans held in their control in 1915 a manufacturing energy, so far as that could be measured by the consumption of coal and steel, equal to more than six times that of all the Allies on the continent; 380,000,000 tons of coal against 45,000,000 tons for France, Russia and Italy combined; that they even held a preponderance over the entire group of Allies including Great Britain. That Empire contributed industrial energy represented by 257,000,000 tons of coal, giving the Allies immediate resources of 300, 000,000 tons. In iron production the Germans controlled plants with a capacity of some 26,000,000 metric tons a year, while that of the Allies was apparently reduced to about 14,000,000 tons. It is probable that both groups were unable to maintain the efficiency of their plants on account of the shortage of labor; but which side suffered most in this respect is not yet clear.

"Some further interesting comparisons may be made. In the consumption of fuels, the United States is easily the foremost nation, consuming an average of over 6 tons per capita. England, Belgium, and Germany seems to be about on the same level, with the consumption of approximately 4 tons per capita.

It is, I believe, conceded by all observers that the industrial output per man is greater in the United States than in any other country; probably about in proportion to the consumption of coal, that is to say, the use of mechanical energy.

A review of the consumption of fuels by the leading industrial nations shows some interesting figures. Russia is apparently in about the same condition that the United States was in 1850. Wood is still largely used as fuel for locomotives, just as it was in this country at that time. The consumption of mineral fuel is about ¼ ton per capita, as it was in the United States in 1850. In the progress of the United States from 1850 to 1918, we find that today we are using 25 times as much coal per capita as we were then; and an estimate of the wealth per capita

as given in the World's Almanac, shows $300 in 1850 and $1785 in 1918. If the productivity of a nation can be measured by this wealth, it would seem that the producing capacity of an American citizen is about six times that of a Russian.

It seems also that, by the same comparison, France is now only as far advanced industrially as the United States was about 1875. This certainly does not mean that specialized industries are not fully as well developed in France as in this country. What it probably does mean is that the mass energy is much less. France consumes only about 1.6 tons per capita, which I think almost certainly means that most of the French people are at work on farms and small shops and not in the factories. They work more with their hands and less with machinery."

The power that lay in the industrial resources thus outlined was abundantly demonstrated by the final event of the war. The vast populations of eastern Europe, meagerly developed industrially, were unable to sustain a thorough military organization. It is probable that they ruined their own armies by making those armies greater than their resources could provide for: the result was hardship, starvation, divided councils, discouragement and finally a collapse of the national morale. The Germans continued to make decided headway until they were finally overmatched by the accretion to the Allies of all the industrial powers of the western nations. Then in their turn, the less highly organized nations of the Teutonic group finally collapsed one after the other. The collapse of each nation took the form of a social and political explosion; their organizations no longer stood the strain.

The industrial power of the United States stimulated to the full by the war reached proportions far greater even than I have indicated. The combined prduction of anthracite, bituminous coal and natural gas in 1918 gave the country fuel resources equal to 775,000,000 tons of coal, in all probability equal to or greater than the production of all the rest of the world put together; this in addition to putting 3,700,000 men into the army as well as sending a considerable number of persons to the war in civil capacities. The steel production of this country likewise ran up to an average of 45,000,000 metric tons for each of the years, 1916, 1917, and 1918, again equal to that of the rest of the world.

Comparisons are said to be odious; and those who draw attention to such statistics as these are sometimes accused of strutting and bragging in the interest of their own country. I wish to disclaim any motive whatever except to express the facts. That great political influences accompany these facts is, I believe, a truth which can be little affected either by arrogance or humility. Arrogance is of course a form of stupidity and it is within the powers of stupidity to injure or destroy the prosperity and prestige of a nation, but this is a matter that has nothing to do with statistics. It is a fact that the United States is today, and promises to continue indefinitely to be, the greatest producer, user and owner of power of all the nations of the earth. This power is

not by any means a fanciful or hopeful appraisal of military strength, but an actual measure of dynamic force, which may be transmuted into military energy in due proportion; but that is almost a negligible factor in the value of it.

If we look upon the English-speaking peoples as an almost homogeneous group, between the parts of which national distinctions are to be of minor importance—a view, by the way, that seems rational and desirable—we shall find that the economic preeminence which they enjoy at present seems guaranteed for the future by a singular combination of the factors to which I have been calling attention. The group occupies only an insignificant fraction of the area of Europe and constitutes only one-tenth of the population of that continent, but the British Isles enjoy advantages in the way of coal resources and a strategic position for trade that gives them an importance altogether out of proportion to these figures. They inhabit or control outside of Europe territories of about 18,000,000 square miles, one-third of the land surface of the world, approximately 150 times the area of the British Isles. These English-speaking people actually occupy the whole continent of Australia, nine-tenths of North America, the temperate regions of South Africa, besides exerting a political control over the major part of Africa and the southern part of Asia. Political control over areas already densely populated is perhaps an advantage in the way of promoting and maintaining trade, but it is only a shadowy and generally a temporary national asset; certainly not to be compared in value with the actual ownership of lands. The areas so owned and settled by white English-speaking people in America, Australia, New Zealand and Africa amount to not less than three times the whole area of Europe, nearly a hundred times that of the British Isles. Moreover these lands are actually the best that are to be found, predominantly temperate in climate, fertile in soil, and apparently supplied with mineral resources even out of proportion to their area. Surely to defend and secure this property to the best and permanent use of the people who own it is a policy that seems reasonable enough and important enough. If the League of Nations now being launched does not prove workable a league of the Anglo Saxons alone would seem able to take its place and guarantee what any other league might guarantee! It is an old saying that "Charity begins at home." We have great resources. One great advantage possessed by the Anglo Saxons is plenty of room. We are not oppressed by the terrors of over-population. Why encourage that terror and bring it nearer by hastening the growth of population by promoting immigration into these vast areas? We talk sometimes of "undesirable neighbors." Is not too great a multitude of neighbors of whatever kind essentially undesirable?

At any rate let us take some measure of the mineral production and resources of this group of people. One purpose in calling attention to

this fact is to show that a discussion of the mining industry of the English-speaking peoples is in most cases to cover a preponderance of the world's output and will therefore indicate the preponderating conditions of the world's industry. It is particularly necessary and desirable for the purposes of this volume that this happens to be the case; for the disturbances of the past five years have almost eliminated statistical information from a large part of the rest of the world.

The following figures show the comparative status of the English-speaking peoples in 1918, with regard to the leading mineral and metallurgical industries.

Pig Iron (Metric Tons)

Estimated World's Production	71,166,000 tons
United States	39,678,000 tons—56 per cent.
British Empire	10,612,000 tons—15 per cent.
Combined	50,290,000 tons—71 per cent.

Copper (Metric Tons)

Estimated World's Production	1,395,200 tons
United States	848,200 tons—61 per cent.
British Empire	106,400 tons— 8 per cent.
Combined	954,600 tons—69 per cent.

Coal (Metric Tons)

Estimated World's Production	1,334,500,000 tons
United States	616,556,000 tons—46 per cent.
British Empire	231,855,000 tons—17 per cent.
Combined	848,411,000 tons—63 per cent.

Gold (Dollars)

Estimated World's Production	$372,518,400
United States	68,493,500—18 per cent.
British Empire	250,824,000—67 per cent.
Combined	319,317,500—85 per cent.

Silver (Fine Ounces)

Estimated World's Production	177,453,300 oz.
United States	67,879,200 oz.—38 per cent.
British Empire	35,625,100 oz.—20 per cent.
Combined	103,504,300 oz.—58 per cent.

Lead (Metric Tons)

Estimated World's Production	1,307,000 tons.
United States	499,600 tons—41 per cent.
British Empire	227,900 tons—19 per cent.
Combined	727,500 tons—60 per cent.

CHAPTER II

VALUE OF MINING PROPERTY

Popular tendency to take fragmentary view of mining industry—Its extent and growth in the United States—Basis of valuation of mines—Average prices and costs—Concurrent fluctuation of costs with prices—The normal profit of mines established by competition with one another, probably as a proportion of the gross output—Types of mining properties—Nature of a mining investment—Known and unknown ore reserves—Dependence of mines on continued development—Calculation of values of mines from known factors.

In this volume I propose to discuss the business of mining on broad lines. Most people who connect themselves with this most important industry are interested only in certain sections of it, even to a point of almost forgetting that there is a mining business outside of their own particular field. People who have been engaged, for instance, in gold mining are apt to think of coal and iron mining as a different business. We find people talking about mining stocks in an unjustifiably restricted sense. A certain group will think of them as referring to shares in highly speculative precious metal enterprises, and will not even consider as coming within their range such really stable and valuable securities as those of the Homestake, Treadwell, or of the many great gold-mining enterprises controlled by British capital. The public does not know that the class of speculative gold and silver mines which depend on the discovery of an occasional bonanza, which is very likely to be exploited much more vociferously in the newspapers and on certain stock exchanges than its value warrants, forms only an insignificant fraction of the mining business. Such properties really depend more on psychology than on values. It is instinctive with a certain fraction of the human race to be enormously attracted by the glitter of gold.

Another section of the mining public is that which devotes itself to speculation in copper shares, ignoring on the one hand, as too speculative, ventures in gold, silver, or lead, and on the other hand, as too slow, ventures in coal, iron, or building material. We have a very much larger group of people interested in coal and iron, who look upon their business as being more allied to manufacturing and devoid of the speculative element that is supposed to enter so largely into the mining business.

Extent and Growth of Mining Business.—As a matter of fact the real mining business of the United States or of the world at large is too vast to be readily comprehended by any single person. The technical part of copper mining or of oil production is in itself a sufficient study

for any man who wishes to devote himself to it; but from the standpoint of the investing public not directly concerned with the management of properties there is no necessity for dwelling in much detail on the separate sections of the mining business. Ultimately there is no essential distinction between mining brick clay and mining diamonds. They are equally natural products; they must be looked for and handled on pretty much the same principles. It is probably a fact that brick clay is just as profitable and just as valuable as the rock which contains the almost infinitesimal proportion of diamonds which give it value.

Products	1898	
	Quantity	Value
Metallic		
Iron, pig, long tons	11,773,934	$116,557,000
Silver, troy ounces	54,438,000	32,118,400
Gold, troy ounces	3,118,398	65,463,000
Copper, sales value, pounds	526,512,987	61,865,276
Lead (refined), sales value, short tons	222,000	16,650,000
Zinc, sales value, short tons	115,399	10,385,910
Quicksilver (value at San Francisco) flasks (75 lb. net)	31,092	1,188,627
Aluminum, pounds	5,200,000	1,716,000
Antimony, short tons	3,238	532,101
Nickel, value at New York, pounds	11,145	3,956
Tungsten ore (60 per cent. concentrates) short tons	....	....
Platinum and allied metals, troy ounces	225	1,913
Miscellaneous	....	....
Total value of metallic products	....	305,482,183
Non-metallic (spot values)		
Fuels:		
Bituminous coal (*a*), short tons	166,593,623	132,608,713
Pennsylvania anthracite, long tons	47,663,076	75,414,537
Natural gas and natural-gas gasoline	....	15,296,813
Petroleum, barrels	55,364,233	44,193,359
Total fuels	....	267,513,422
Structural materials	....	123,592,445
Abrasive materials	....	1,098,784
Chemical materials	....	12,387,719
Pigments	....	2,962,055
Miscellaneous	....	10,236,246
Total value of non-metallic mineral products	....	417,790,671
Total value of metallic products	....	305,482,183
Estimated value of mineral products unspecified	....	1,000,000
Grand total	....	$724,272,854

(*a*) Includes a small amount of peat in 1908 and 1918.

It may be a matter of surprise to many business men to learn that in 1918 the total mineral production of the United States in a crude form at the mines or metallurgical works was $5,526,162,000; that the total number of men employed in this business must be approximately 2,500,000; that of this total output the value of gold and of silver are each less than 1¼ per cent.; copper less than 9 per cent.; while pig iron accounts for 21 per cent.; coal, 33 per cent.; natural gas and petroleum over 5 per cent. lead, zinc, and ferro-alloys are each considerably in excess over gold; and structural materials such as clay, cement, lime, and stone equal the value of copper. The contemplation of these figures will be a great help to one's sense of proportion in the mining business. I accordingly present the following tables of mineral production from the reports of the U. S. Geological Survey:

1908		1918	
Quantity	Value	Quantity	Value
15,936,018	$254,321,000	38,981,308	$1,296,193,508
52,440,800	28,050,600	67,879,206	67,879,206
4,574,340	94,560,000	3,313,373	68,493,500
942,570,721	124,419,335	1,908,533,595	471,408,000
325,595	27,444,715	558,256	79,561,350
190,749	17,930,406	492,405	89,618,000
19,752	872,446	32,883	3,863,752
11,152,000	2,434,600	....	41,159,000
2,246	359,360	5,183	1,306,116
....	....	882,000	401,000
671	229,955	5,041	6,802,000
750	14,240	38,831(*b*)	4,023,757
....	467,081	....	22,359,989
....	550,744,388	....	2,153,139,000
332,573,944	374,268,268	585,990,261	1,466,047,243
74,347,102	158,178,849	88,237,575	336,480,347
....	54,640,374	....	230,840,000
179,572,479	129,706,258	350,131,000	690,190,000
....	716,793,749	....	2,723,557,690
....	261,757,143	....	442,839,601
....	1,074,039	....	2,734,692
....	31,925,866	....	110,065,326
....	7,603,269	....	28,044,337
....	25,646,516	....	59,081,022
....	1,044,800,582	....	3,366,322,668
....	550,744,388	....	2,253,139,000
....	250,000	....	6,700,000
	$1,595,794,970		$5,526,161,668

(*b*) Figures for 1917; 1918 not available.

PRICES OF SILVER, COPPER, LEAD, AND ZINC, 1850-1918

Year	Silver,[a] fine oz.	Copper,[b] pound	Lead,[c] pound	Zinc,[d] pound
1850	$1.32	$0.22	$0.05	.....
1851	1.34	0.166	0.05	.....
1852	1.33	0.22	0.05	.....
1853	1.35	0.22	0.06	$0.055
1854	1.35	0.22	0.06	.....
1855	1.34	0.27	0.07	.....
1856	1.34	0.27	0.066	.....
1857	1.35	0.25	0.06	.....
1858	1.34	0.23	0.06	.....
1859	1.36	0.22	0.055	.....
1860	1.35	0.23	0.056	.....
1861	1.33	0.22	0.05	.....
1862	1.35	0.22	0.06	.....
1863	1.345	0.34	0.06	.....
1864	1.345	0.47	0.07	0.139
1865	1.337	0.392	0.066	.....
1866	1.339	0.342	0.07	.....
1867	1.33	0.254	0.065	.....
1868	1.326	0.23	0.065	.....
1869	1.325	0.242	0.06	.....
1870	1.328	0.212	0.06	.....
1871	1.325	0.241	0.06	.....
1872	1.322	0.356	0.064	.....
1873	1.297	0.280	0.06	.....
1874	1.278	0.220	0.06	.....
1875	1.24	0.227	0.058	0.07
1876	1.16	0.21	0.061	0.072
1877	1.20	0.19	0.550	0.06
1878	1.15	0.166	0.036	0.049
1879	1.12	0.186	0.041	0.052
1880	1.15	0.214	0.05	0.065
1881	1.13	0.182	0.048	0.052
1882	1.14	0.191	0.049	0.053
1883	1.11	0.165	0.043	0.045
1884	1.11	0.13	0.037	0.044
1885	$1.07	$0.108	$0.040	$0.043
1886	0.98	0.111	0.046	0.044
1887	0.99	0.138	0.045	0.046
1888	0.94	0.168	0.044	0.049
1889	0.94	0.135	0.039	0.05
1890	1.05	0.156	0.045	0.055
1891	0.99	0.128	0.043	0.05
1892	0.87	0.116	0.041	0.046
1893	0.78	0.108	0.037	0.04
1894	0.63	0.095	0.033	0.035
1895	0.65	0.107	0.032	0.036
1896	0.68	0.108	0.03	0.039
1897	0.60	0.12	0.036	0.041
1898	0.59	0.124	0.038	0.046
1899	0.60	0.171	0.045	0.058
1900	0.62	0.166	0.044	0.044
1901	0.60	0.167	0.043	0.041
1902	0.53	0.122	0.041	0.048
1903	0.54	0.137	0.442	0.054
1904	0.58	0.128	0.043	0.051
1905	0.61	0.156	0.047	0.059
1906	0.68	0.193	0.057	0.061
1907	0.66	0.20	0.053	0.059
1908	0.53	0.132	0.042	0.047
1909	0.52	0.13	0.043	0.054
1910	0.54	0.127	0.044	0.054
1911	0.53	0.125	0.045	0.057
1912	0.615	0.165	0.045	0.069
1913	0.604	0.155	0.044	0.056
1914	0.553	0.133	0.039	0.051
1915	0.507	0.175	0.047	0.124
1916	0.659	0.246	0.069	0.134
1917	0.824	0.273	0.086	0.102
1918	1.00	0.247	0.071	0.091

[a] Report of Director of the Mint, pp. 212–213, 1914. Equivalent of fine ounce based on average price and average rate of exchange. For 1916 and 1917 dealers' buying price, New York. For 1918 average price supplied by Bureau of the Mint.

[b] Weed, W. H., Copper handbook, vol. 11, pp. 1339, 1343, for years 1850–1903. By computation from data for years 1850–1860, p. 1339. Survey computations for electrolytic copper since 1904. For 1916, 1917, and 1918, sales price all marketable grades.

[c] New York price, Ingalls, W. R., Lead and zinc in the United States, p. 203, 1908. U. S. Geological Survey since 1904. For 1916, outside spot quotations, New York. For 1917 and 1918 average sales price, all grades.

[d] New York price, 1875–1904, Ingalls, W. R., Lead and zinc in the United States, p. 342, 1908. St. Louis price, U. S. Geological Survey, since 1904. The zinc price for 1915, 1916, 1917 and 1918 is average sales price of zinc, all grades. Oral communication from C. E. Siebenthal for 1853 and 1864.

TOTAL VALUE OF MINERAL PRODUCTS OF THE UNITED STATES FROM 1880 TO 1918.

Year	Metallic	Nonmetallic	Unspecified (metallic and nonmetalic)	Total
1880	$187,880,880	$173,581,917	$6,000,000	$367,462,797
1881	189,413,459	207,207,019	6,500,000	403,120,478
1882	215,820,070	230,785,547	6,500,000	453,105,617
1883	197,881,610	243,679,889	6,500,000	448,061,499
1884	180,284,208	221,755,346	5,000,000	407,039,554
1885	172,218,218	242,332,845	5,000,000	419,551,063
1886	204,399,872	250,985,090	800,000	456,184,962
1887	240,791,068	294,041,980	800,000	535,633,048
1888	242,010,000	310,888,983	900,000	553,798,983
1889	250,324,369	291,001,413	1,000,000	542,325,782
1890	303,440,430	310,988,907	1,000,000	615,429,337
1891	280,484,844	319,363,338	1,000,000	600,848,182
1892	283,715,295	337,516,444	1,000,000	622,231,739
1893	223,153,770	321,339,395	1,000,000	545,493,165
1894	186,835,353	362,409,394	1,000,000	550,244,747
1895	248,033,039	393,658,083	1,000,000	642,691,122
1896	252,075,130	387,965,870	1,000,000	641,041,000
1897	269,934,178	380,677,600	1,000,000	651,611,778
1898	308,247,446	417,794,018	1,000,000	727,041,464
1899	483,520,531	525,571,880	1,000,000	1,010,092,411
1900	513,731,959	594,194,796	1,000,000	1,108,926,755
1901	493,313,578	660,764,256	1,000,000	1,155,077,834
1902	604,517,044	722,433,728	1,000,000	1,327,950,772
1903	588,753,010	905,628,365	1,000,000	1,495,381,375
1904	501,114,224	859,074,529	400,000	1,360,588,753
1905	702,584,608	921,181,524	400,000	1,624,166,132
1906	886,179,981	1,016,390,015	200,000	1,902,769,996
1907	904,093,201	1,165,748,197	100,000	2,069,941,398
1908	550,744,388	1,043,702,454	250,000	1,594,696,842
1909	754,940,809	1,131,515,921	300,000	1,886,756,730
1910	749,876,234	1,241,039,986	300,000	1,991,216,220
1911	680,888,929	1,245,676,783	250,000	1,926,815,712
1912	866,381,073	1,378,310,236	500,000	2,245,191,309
1913	883,222,012	1,557,976,159	420,000	2,441,618,171
1914	691,081,734	1,426,754,508	470,000	2,118,306,242
1915	991,729,648	1,398,565,121	7,450,000	2,397,744,769
1916	1,620,508,000	1,878,464,000	15,000,000	3,513,972,000
1917	2,086,233,000	2,915,326,000	5,700,000	5,007,259,000
1918	2,153,139,000	3,366,323,000	6,700,000	5,526,162,000
Grand total..	22,143,496,000	31,652,615,000	91,440,000	53,887,551,000

It is to be understood, of course, that market values are not received by producers for metals in ore and intermediate products, nor always for metals in marketable form; that payment is made in accordance with contracts for treatment or sale; and that, therefore, average daily quotations do not necessarily agree with average prices received.

I have not been able to cover the whole field of the mining business, but I shall endeavor to present some idea of the business as applied to coal, iron, gold, copper, silver, lead, and zinc. These materials amount to over 75 per cent. of the total mineral output and it is fair to believe that the principles governing the exploitation of this much will apply also to the remainder.

The above tables should not be dsmissed without some further comment. They emphasize not only the importance of the mining business, but also its increasing importance. The mineral output per capita in the United States in 1880, which was a boom year, was less than \$7.50, while in 1918 it had risen to \$50. There is not the slightest indication that the increase in the use of minerals has anywhere nearly reached its limits. On the contrary, the development is in full career and is likely to continue for many decades. So long as the United States has two thousand billion tons of accessible coal within its borders and vast tracts of irrigable and swamp lands still undeveloped and a rapidly increasing population daily becoming more accustomed to increasing standards of efficiency and an increasing scale of comfort, we may look forward to great increases of business. There is no other field in which activity promises to be more widely extended than in mining which furnishes the basis for most of the characteristic manufactures of modern civilization.

Valuation of Established Mining Concerns.—It is in this particular field also that the process of consolidation of unit enterprises into larger, more stable, and more effective groups is most noticeable. It is inevitable that this process will mean an extension of ownership among a larger number of holders, concurrent with the concentration of management in proportionately fewer but more effective hands. The great enterprises of the present are usually far beyond the resources of any individul capitalist. Shares of most of our great corporations are divided among many thousand people. The expansion of this kind of ownership is as inevitable as the expansion of business itself. I regard it, therefore, as an important function of the mining engineer and mining investor of the immediate future to study and fix the valuation of industrial shares, based partly or wholly on mining enterprises, as well as of single mining properties. My purpose is to explain how the valuation of mining properties depends on some cardinal principles that are easily understood in general terms, but may easily be obscured in concrete cases. These principles of course apply not to speculation but to serious

investment. The basic factors are: first, average market prices; secondly, average costs; thirdly, the life of the mine. While each of these factors is so easily understood as to be practically axiomatic their application always involves questions that are not always easy to answer.

Average Prices.—The average price of any article for a period of years in the past is usually very easy to determine, but we are immediately confronted with the fact that prices determined with accuracy for certain periods of years do not agree with equally well determined prices of other periods of years. For example, the price of copper for the last sixty years has averaged 16.33 cents per pound. For the last twenty years it has averaged 16.89 cents per pound while for the last ten years it has averaged 17.96 cents per pound. Now since the question is not what prices have been in the past, but what they are likely to be in the future, it is evident that we must select from these various averages the one that seems most likely to conform with the probable conditions ahead of us. Such a selection involves the consideration of a great variety of subjects. A thing that throws most light on this problem is the course of prices themselves. If these prices are plotted in a curve for a long period of years it will be found that there have been a series of high-price periods followed by another series of low-price periods. It may and will make a good deal of difference with our prediction of the future whether the crest of each high wave is higher than that of the one preceding it, and the low wave not quite so low as the one that preceded it. If we find such a state of affairs, we are probably justified in concluding that the average price of such a commodity is rising.

One will be influenced in like manner by the demand for a given article in comparison with other articles. If we should find, for instance, that the amount of lead used in 1890 was equal to the amount of copper used, while in 1900 only one-half as much was used, and in 1910 only one-quarter as much, it would seem to be well worth while to look into the reasons for such changes. These reasons might be complex and obscure. It might be that they would argue either for higher or for lower prices for either of the articles in question. If the consumption of lead were proportionately diminished, it might be explained by a deficient supply which would argue for higher prices, or it might be due to a substitution of other materials for the uses to which lead had been put; which would argue for lower prices. It is well to point out that these are precisely questions that people engaged in trade are constantly considering. But for the man who is looking for general tendencies and not for the conditions of the moment the ideas of such people are too much fixed on near considerations. Their eyes are apt to focus not on the developments of a decade, but on those of a week or month. It is against the judging of great and stable securities on these momentary considerations that it is most necessary to protest.

Average Costs.—The determination of average costs is the principal matter discussed in this volume. It is necessary to introduce here a consideration that is easily overlooked, namely, that if prices vary, costs vary also, but not to the same extent. The value of securities is too often affected by a hasty conclusion on the part of the public that a rise in prices will go wholly to profits, or that a drop in prices will be taken wholly out of profits. As an illustration of this fallacy I reproduce here an article published in the beginning of 1908 in the *Engineering and Mining Journal* on the *Vanishing Point of Profits:*

Concurrent Fluctuation of Costs and Prices.—"The Federal Mining and Smelting Company's report for 1907 shows a net profit of $2,232,249 after taking out a 'development account' of $300,000. This came from 130,373 tons of concentrates containing 3,689,298 oz. of silver (worth 68 cents per ounce, or $2,508-722.64) and 59,746 tons of lead (worth $116 per ton, or $6,930,536), the total gross value being $9,439,258.64). On this output the profits amount to 23.6 per cent. and the costs must therefore be 76.4 per cent., giving an apparent cost for lead of 4.43 cents per pound and for silver of 51.95 per ounce.

"At first thought one is apt to assume that with costs the same the company would receive no profit unless the prices were above 4.43 cents for lead and 51.95 cents for silver. How false such an assumption would be appears from the following:

"The Cœur d'Alene mining companies, of which this is one, do not smelt their own concentrates but sell them to smelting companies under contracts somewhat as follows: The smelter pays for 90 per cent. of the lead at 90 per cent. of the New York price, or 81 per cent. of the full quantity and price when lead sells at 4.10 cents per pound or under. When the price rises above 4.10 cents per pound the smelter pays 81 per cent. and one-half the additional price. Thus if lead sells at 4.50 per pound the smelter pays 81 per cent. of 4.10 plus one-half of 0.40 = 3.521. The smelter pays for 95 per cent. of the full value of the silver. A freight and treatment charge of $16 a ton is deducted from the value of average concentrates. Applying this rule to the output for 1907 we find that the cost of producing concentrates was $23.39 a ton, thus:

	Selling price	Contract price
Lead	5.80	4.171
Silver	68.00	64.60

916.54 lb. lead at 4.171 cents	$38.23
28.298 oz. silver at 64.60 cents	18.28
Total value per ton	56.51
Freight and treatment charge	16.00
	$40.51
130,373 tons at $40.51	$5,281,410.23
Profits	2,232,249.00
Total cost of production	3,049,161.23

$$\frac{\$3{,}049{,}161.23}{130{,}373} = \$23.39 \text{ cost per ton produced}$$

"Now let us see what would happen to the Federal Mining and Smelting Company were the prices reduced to the point where profits apparently vanish according to 1907 experience. The concentrates contained: lead, 45.827 per cent., 916.54 lb., and silver, 28.298 oz. per ton. The value is figured as follows:

	Selling price	Contract price
Lead	4.41	3.426
Silver	51.95	49.353

916.54 lb. lead at 3.426 cents	$31.40
28.298 oz. silver at 49.353 cents	13.97
Total value	$45.37
On this our costs are:	
Freight and treatment charge	$16.00
Mining and milling	23.39
	$39.39

"We have a profit remaining of $5.98 per ton. This on 130,373 tons would be $779,630.54 or 34.9 per cent. of the profit at 1907 prices. On this basis we may figure the real vanishing point for lead as follows:

"Let the silver price remain stationary and we shall have in our concentrates silver worth $13.97. Our cost is $39.39; therefore, 916.54 lb. of lead must be worth $25.42 or 2.773 cents per pound. But as this is only 81 per cent. of the selling price the latter will figure 3.421 cents. It would seem, therefore, that we have reached the vanishing point of profits as far as the Federal Mining and Smelting Company is concerned with lead at 3.421 cents and silver at 51.95 cents at New York.

"But this deduction may also be wrong, for the company has a chance to select its ores and produce a higher grade product. Suppose it produces from its more favorble mines only 65,000 tons of concentrates instead of 130,373 tons, and that the selected concentrates carry 56 per cent. lead and 38 oz. silver. Suppose this ore cost 10 per cent. more for mining and milling and 12.5 per cent. more for freight and treatment and we have a cost of

Mining and milling	$25.75
Freight and treatment	18.00
	43.75

"But the ore will be worth as follows:

Lead, 1120 pounds at 2.773 cents	$31.06
Silver, 38 ounces at 49.353 cents	18.75
	$49.81

"Thus we still have a profit of $6.08 per ton or $395,200, and in addition the company is keeping in its mines a very large amount of ore that may be available at better prices. With the above grade of concentrates, supposing that silver remains the same, the vanishing point of profit on lead will be reached at 2.230 cents by contract or 2.753 cents at New York.

"Even yet we have not reached the limit of the company's resources. It is

safe to say that if lead had to be sold at 3 cents per pound, supplies to the mines would be cheaper and wages could be reduced."

General Principles of Relation of Cost to Price.—A simpler explanation of the point explained here may be taken from the following considerations: A normal price for copper may be assumed to be 15 cents a pound. Let us suppose that a company under ordinary conditions can produce copper for 10 cents a pound, making, therefore, a normal profit of 5 cents. Let us suppose that copper goes up to 20 cents a pound and analyze roughly the conditions which would take place under such a rise of price and the effect of those conditions on the cost of production.

Such a considerable rise of price could only be due to a deficiency in the supply. Apart from the cutting off of important sources of supply by war or other calamity, generally this deficiency must be caused either by a shortage of ore or by a shortage of labor or by both. In the case of an individual mine a shortage in the supply of ore would naturally mean either impending exhaustion or an insufficient amount of development. In an ordinary mine the volume of copper could be increased by utilizing some low-grade ores which would not ordinarily be worth working. Under the stimulation of a higher price the management would naturally utilize these low-grade ores which it could not work at 10 cents or even at 15 cents copper. It follows as a natural and almost inevitable result that each mine would, at 20 cents copper, undertake the working of a proportion of lower grade stuff at very much increased cost.

But the mere undertaking of increased production implies an increased use of labor. Both the efficiency and the supply of labor are variables. The efficiency generally depends on the supply. Where an enterprise is well established and wages are high the number of miners is apt to exceed by a certain percentage the demand. In other words, ther is always a number of men looking for a job. The existence of a crowd of unemployed men always acts as a spur to the exertion of those who are fortunate enough to have jobs. The sudden expansion of the business will take away the surplus of labor. The men who come out of the shafts at night no longer see their employment threatened by competition. They accordingly take things easier and the immediate result is a lowering of efficiency. This means an increase in cost. Sometimes it means a very great increase of cost.

If the enterprise is not paying a rate of wages sufficient to cause an over-supply of labor under normal conditions, then any attempt to increase the scale of operations will be immediately thwarted by lack of men to do the work. If the company finds it necessary under such conditions to increase its operations it must first secure an increased supply of labor. The usual way out of such a difficulty is to raise the wages.

Furthermore, if copper is scarce and in great demand it is usually a corollary that other products are scarce and in great demand. Very likely the railroads will be congested with freight; manufacturers of machinery overcrowded with orders. These are all factors that increase cost. A mining company wishing to get out a large output of 20-cent copper, when it usually gets only 15 cents, finds itself under a drain of heavy expense, bidding up prices of labor and supplies of all kinds in order to accomplish its purpose. In extreme cases it is quite probable that the cost is so much increased by these factors as to absorb the whole advantage of the increased price. That a certain proportion will be absorbed may be considered inevitable.

The phenomenon of such increases of cost through such conditions of trade as have been described is familiar to any businessman who has lived through one or two panics. When you see in the newspapers or in reports of industrial concerns complaints of a shortage of labor and the inefficiency of labor you may prepare for a panic.

It is a corollary from the same considerations that in periods of depression costs will be reduced. Let us suppose that our copper company which has been used to 15-cent copper finds itself unable to sell for more than 11 cents. This must mean that the demand for copper has diminished. It is no longer necessary to produce so much. There is no longer the necessity for active development. Copper that is needed can be produced from selected ores. Since fewer men will be needed the work will be done by selected men who will work under a greatly increased stimulus of competition. Wages may be reduced. The cumulative effects of such conditions may mean that the company which has produced copper normally at 10 cents may produce it for a period at 8 cents or even less and of course find a considerable margin of profit.

The Normal Profit of Mines.—The recent war brought about such a disturbance of the commercial conditions which we were accustomed to consider as normal that doubts have arisen and still exist as to how soon, if ever, there will be a return to the former basis. That basis was not, of course, uniform or stable but represented the average of demand, production and prices which ebbed and flowed under the impulse of such industrial excitements and reactions as have just been enumerated like irregular and unpredictable, but recurrent, tides. There has always been the same difficulty in perceiving the average price of a metal as there is in perceiving the exact level of the sea: observers concern themselves not so much with the level of any particular moment as with a record of the fluctuations from which they estimate an average as a mathematical conception. But a World War carries with it the possibility of being a human earthquake which may change the basis of commercial calculations just as a natural earthquake, which of course, is merely the expression of internal stresses in the earth's crust, may make

a change in the level of the sea. We have had with this human earthquake a tidal wave of high prices for labor and commodities. Is it merely a tidal wave which will flow back in its entirety, carrying the price level temporarily by sheer momentum down below normal? or is it a permanent advance?

We know that prices will fall below the war peaks, for in most commodities they have already done so; but a recession does not necessarily mean a return to the former average. The prices are never stationary; they are always rising or falling. The question is whether in the post-war period they are likely to rise and fall above and below a different level than before. There are apparently good reasons for expecting that the general level will be higher, at least for a considerable period.

1. Prices of commodities have some relation to the rate of wages. It is true that in all industrial countries there has been a steady increase in the output per man which justifies the raising of wages; but the effect of a war is to raise the wages without increasing the productivity, in fact actually decreasing it. There is a passive resistance on the part of employees to a reduction of wages and to a certain extent this resistance may not be overcome in the process of readjustment: they may succeed in getting more dollars but have the same amount of commodities as before, that is, wages will only *seem* to be higher and commodities will sell at higher prices.

2. The enormous national debts may have a considerable effect in holding up prices. Taxes are bound to remain greatly increased and wherever possible people will add the amount of taxes to the price of commodities. Indeed this is inevitable; for on the theory that prices are some function of the cost, that is, when costs increase prices increase, it is self-evident that increased taxes mean increased costs and higher prices.

But as a practical matter the price level is probably less important to the producers than we are accustomed to imagine. The products of mines are staples, indispensable to the life of civilization. There is a constant demand for them. Some mines can produce more cheaply than others. The cheap producers are profitable; the higher cost producers are only profitable during temporary waves of sharp demand Following out this line of reasoning it is easy to see that the average profit of a mine is a measure of its advantage compared to other mines; in other words it is determined by competition with other mines. It will be found, for instance, that a given property is able to pay one quarter of its gross output in dividends. This simply means that three quarters of its output is consumed in costs, of one form or another, and that the remaining quarter goes to the stockholders. This proportion varies from year to year, but in the long run an average is established and maintained. It seems logical to believe that this proportion will remain

as fixed as ever, whatever the level of prices. Thus we may believe that a copper mine which will pay 3 cents a pound if the selling price of the metal averages 12 cents will be able to pay 6 cents a pound if the metal is to average 24 cents. I am disposed to accept this proposition as a sort of general principle. Perhaps it is an important thing to bear in mind during the uncertainties attending the readjustment and reconstruction that must follow the war. There is, of course, some danger in confusing the changes in the condition of individual mines with the changes in industrial conditions.

If this proposition is true it involves the following consequences: (1) That changes in price levels which affect all commodities alike are not of fundamental importance to producers, for it is nothing but a change in the value of a dollar. If wages are doubled, costs will be doubled, prices will be doubled and each producer will have the same amount of goods as before. (2) But a rise of prices is unfavorable to all forms of fixed income and a lowering of prices is favorable to fixed income. Thus if prices are to be double those of the pre-war period the general effect will be to repudiate, or cancel, half the bonds and mortgages of the world, including all national debts, except of course those that were floated during the period of inflation. The nominal value of the older debts, will remain the same of course, the real value will be reduced one half. (3) In the case of staples, including mines, mining dividends and mining stocks, the real value will remain the same, but the nominal value will be doubled.

Thus it is reasonable to conclude that the question of a higher or lower level of prices for the future has a distinct bearing on allocating the cost of the war, and that the influences that control it wear a rather important aspect.

In view of the uncertainty which obtains just now as to the effect of these influences (in reality merely an uncertainty as to the future purchasing power of the dollar) it seems logical to give considerable attention to the cost of commodities measured in the commodities themselves. This it seems to me is likely to remain nearly uniform so long as the natural factors remain constant. The output per man from a given deposit will surely return to the average established by competition before the war and both costs and prices will return to about the same relation to the rate of wages. All this brings us to the conclusion that the results obtained up to the end of 1915 are much more valuable as illustrations of permanent influences than those of the three following years, and in the discussions which are to follow the records from which important conclusions are drawn usually end with the year 1915; those of the following years being discussed mainly to illustrate the nature and degree of the interruption of normal conditions. The practical way to draw valid conclusions as to the value of mines is therefore to figure out the per-

centage of the gross value that could be paid in dividends under the pre-war conditions, and assume that the same percentage could be paid under any level of prices which may become permanent.

Reduction of Costs Per Ton not a Sign of Prosperity.—Also we should not fail to note another general tendency in every important mining enterprise, and that is the tendency for costs to become reduced as times goes on. In part this tendency is due to general improvements in machinery and methods, new inventions, better transportation facilities, etc. which the individual enterprise shares with the industry at large. But the larger part comes from the settling down of the enterprise itself to a steady gait, to its better organization, to the better results secured from labor, and usually to a larger scale of operation whereby the unit cost of production is reduced by increasing the number of tons by which the fixed items on the cost sheet are divided. It is furthermore to be noted that a diminished cost per ton due to these causes hardly ever results in an increased profit per ton when the price of the product remains constant or even when it increases. Many reasons bring about this result, but the most important undoubtedly is the equally general tendency to a reduction with time in the metallic content of the ton of ore. This in many cases comes from an actual impoverishment with depth, which forces the adoption of better methods, resulting in lower costs through the inexorable necessity of diminishing returns. The Calumet & Hecla is a conspicuous example of the achievement of lower costs under the necessity imposed by a fall of one-half in the yield of its ore. But the enlarged scale of operation itself works in the same direction even more effectively. The mill or reduction works is nearly always overbuilt for the ore developed. To get a low cost per ton is must be operated to its capacity. This puts a strain on the mine, with the result that in order to keep up the tonnage certain stopes are worked which yield rock from which only a small profit or none at all is realized. Furthermore, in many mines with ores of several grades the lowering of costs automatically, as it were, enlarges the available tonnage that may be handled with some profit, the effect being precisely the same as an increase in the price of the product. This result is shown very clearly by several of the newer Lake Superior copper mines, where an enlargement of the mill and of operations generally has resulted not only in a diminished cost per ton, but also in a diminished yield per ton. It is also conspicuously shown by most of the gold mines on the Rand.

These considerations may be summed up in a few words. A diminished metal content in the ton of ore makes it necessary to reduce costs, and a reduced cost per ton, which always comes with time and enlarged operations, permits the handling at a profit of lower and lower grade ore. Therefore, quite independently of the course of prices, we have a tendency for cost and metallic content per ton to fall together,

and the net result of this tendency almost invariably is a diminished profit per ton.

From these considerations it will appear that there is no great danger in calculating on average costs bearing a certain proportion to average prices. I feel like insisting that the only rational way of calculating mining profits is to consider both with the greatest possible care.

In this connection I wish to point out that in calculating costs great attention must be given to capital charges as well as to operating charges. Undue attention to details of cost and too much attention to statements covering single months or years are apt to befog one's vision as to the real proportion of capital expenses. This is an error into which I have been particularly careful not to fall.

In the discussion of costs to be presented in the following chapters I have given great attention to the problem of entering in capital or construction costs in due and fair proportions. It seems worth while to state at the outset that in the metal mines of the United States the total cost for the life of a mine is apt to exceed the operating charges from 20 per cent. to 40 per cent.

Nature of Mining Investments.—Mining companies may be divided into:

I. Those which own a single mine confined to a single orebody or a definite tract.

II. Those that own various mines each with its individual capabilities for expansion.

III. Those that combine mining with other business such as transportation, smelting, or manufacturing.

It should be plain that these variations afford a great range of considerations from simple to complex, and that there is room for the exercise of much talent and experience in the appraisal of the earning power of a property or of a company. In the case of a circumscribed property it is often possible to fix a valuation from purely physical considerations; but in the case of corporations doing a general mining business there are brought into prominence the technical and financial ability of the management and the financial state of the corporation. By the last consideration we mean whether it is in debt or not and whether its indebtedness can easily be disposed of, or whether the debts will drown the earning power of the property rendering the equity of it only nominal value.

Now in the case of mining property of all kinds there is one salient fact that should never be forgotten for a moment, namely, *that it is a wasting asset which is always in process of distribution.* This is true whether we are to consider only a single producing unit or a vast aggregate of such units.

A mine has been likened to a bank account. The analogy with an account in a going bank is imperfect, because such an account may be

swelled by new deposits, while new ore cannot be added to that which a mining property already possesses, although the actual amount may not be known until the property is exhausted. With an account in a bank being wound up by a receiver, however, the analogy is absolute. The receiver, as he realizes on the assets, pays the account back to its owner in instalments which are called dividends. Dividends from mining property are of precisely the same nature, namely, they are not interest on capital which remains unimpaired, but are the capital itself distributed in instalments. When the last asset is realized, the payment of instalments ceases and nothing is left.

It would be a considerable public service if one could make clear to investors the difference between an ordinary investment and a mining investment. What is an ordinary investment? The term may describe real estate, railroad securities, mortgages, etc., in which the property is permanent and in which it is assumed that the principal will remain intact. The question that determines the value of such property is: What annual income does it yield?

In the case of a mining property two concurrent questions must be answered in order to determine its value: What will be the sum total of dividends? and how long will it take to realize them?

Known and Unknown Ore Reserves.—It must be confessed that many of the conclusions drawn by mining engineers in answer to these questions have been proved false. The explanation is that such engineers, like other people, are imposed upon by the fashionable opinions of a particular time. We have passed through a period in which it was an intellectual habit to lay too much stress on ore "in sight," the "estimation of ore-reserves," and to engage in a line of reasoning warped by a fundamental misconception and bound to lead to an incorrect result.

A valuation of a mine based upon a given ore reserve must generally contemplate that the value of the property will decline year by year as those reserves are encroached upon. This indeed may, and does, happen. But there are innumerable cases where it does not happen and these cases are generally those of the best mines. There are plenty of mines that had, say, three years ore in sight twenty years ago, or ten years ago. If the ore in sight were a measure of their value these properties would long ago have been exhausted and forgotten: but in fact these very mines may be producing several times as much and may be worth several times as much as they were at the beginning of the period, and today they may still have the same three years ore in reserve. Almost all the greatest mines in the West are examples, specifically the mines at Butte, Coeur d'Alene, Park City, Tintic, Cripple Creek, Bisbee, Clifton-Morenci, Globe, Jerome, Cananea—most of the great copper and lead mines of the country and of the world. Even the "Porphyry Copper" mines are no exception, nor are the copper and iron mines of Lake Superior. In short

there has been so much confusion of ideas between the measuring of ore reserves and the other factors that determine the progress of mining that some discussion of the matter does not seem out of place.

There are certain historical circumstances that have had an important bearing on the development of ideas on this subject. I remember some twenty years ago hearing Mr. W. E. Newberry, a well known mining engineer at that time, remark that if one would give him the first five hundred feet of a mine he would take that part in exchange for all the rest. Mr. Newberry's experience had been chiefly in the gold and silver-lead mines of Colorado and elsewhere. At that time his conclusion based upon his experience, was not in the least illogical. The facts were that up to that time the mining of lead, silver and gold in this country and throughout the world was conducted mainly in the zone of "secondary enrichment" or oxidation. The processes in general use were those that dealt with such ores. Gold ores were expected to be "free-milling," that is amenable to the simple process of stamp-milling and amalgamation. Silver lead ores were quite generally found to be products of a natural concentration of lower-grade original masses of zinc, lead and iron sulphides. It was profitable to ship the small bodies of rich galena or carbonate to custom smelters; the cases in which it would pay to put up expensive plants to treat the mixed ores were at that time few and far between. The capital for such enterprises was not easily to be found and it was hazardous to advise the investment of it. The necessary development of the art of mining; the cyanide process, the flotation process, large scale application of power, adequate transportation, etc., was either not yet perfected or not generally applied. But this was not all: the zone of secondary enrichment very frequently increased the width of veins by causing depositions in the walls. Passing through this, one was confronted by three formidable changes—lower-grade ore, diminished volume and a chemical composition different from that encountered before, requiring for utilization new processes which might either not exist or be commercially inapplicable. What more natural than to suppose that all these facts were equivalent to the actual "playing out" of the deposit? Instance could be piled on instance, in all parts of the world, where mines came to an abrupt end, as money makers, from these causes.

Scientific theory seized upon these factors and gave weight to them to an extent far beyond the degree which subsequent developments have warranted. In the Lake Superior iron ranges, Van Hise perceived that the commercial ore bodies were concentrations of iron oxides coincident with oxidation proceeding from the surface. In other regions such oxidation had rarely been found to go below one thousand feet from the surface. What more natural than to assume that it would go no deeper in Lake Superior and that the iron ore bodies would go no deeper? The reasoning

seemed so probable as to be almost conclusive; and geologists twenty-five years ago felt no confidence in those deposits extending much below the bottom of the mines as they were developed at that time. Mining men followed their example. In the great development made since that time innumerable instances have been found where Van Hise's expectation of a limited depth has been found to be true; for instance on the Mesabi Range where scarcely a deposit has gone below 500 feet. But in other districts, such as the Gogebic, Marquette and Menominee Ranges, his expectation was not true; great ore-bodies have been found at depths approaching 3,000 feet and the limit of commercial availability is still unpredictable.

But it is easily seen that reasons, both of fact and inference, were very strong for an attitude of caution. Mining engineers were naturally anxious that the clients whom they advised should not lose money and the danger of losing it through a rash confidence in the persistence of ore-bodies to any great depth, or distance, beyond actual disclosures seemed very great.

During the past ten years much has been done to show the inadequacy of the conclusions that would be based on this line of reasoning. In important districts where a portion of the earth's crust is permeated by an extensive mineralization the matter of finding ore is a perpetual and integral part of the process of extracting it. Before such a district is worked out the openings grow in length to hundreds, or thousands, of miles; and the cost of them grows into millions and scores of millions of dollars. To expect all this or even a respectable fraction of it to be done in advance of the extraction of ore is simply out of the question. The management that would venture to embark capital in such a project would involve the company in hopeless insolvency and a stock holder might reasonably ask for a receivership from the courts on the ground that funds were being misapplied. The objections to such a course would not be wholly financial either. In most cases there would be physical difficulties in finding the ore by a mere process of advance exploration, for unless some of it were removed the miner would have no intelligent means of conjecturing where to look for the extensions. A body of ore in solid rock, we must remember, is enclosed not by lines or areas but by volumes. Suppose we have made a discovery of such ore and we wish to explore its continuation and form an idea as to its extent; suppose we enclose our discovery in an imaginary cube; do we not have to remember that a cube has six sides? If the ore body pursues an irregular and erratic course through the rock can it not go out of your cube through any one of those six sides? If so, what geometrical areas is it necessary to explore before you are sure that the ore body does not pass through one of those sides? Is it not better, instead of trying to traverse a cubic volume of rock with exploratory openings, merely to make the farther openings in the

ore itself, and to find the continuation of the ore merely by the continuation of your profitable mining? All these questions inevitably answer themselves in the miner's mind before he has gone very far. He learns, but sometimes does not state very clearly, that if the mine is any good, it is impossible to do in advance development work that will take the measure of it. Instead of measuring the mine by the amount of ore he has in reserve, he learns how much work he must do and how much money he must spend in order to open up enough ore to keep up his output, and he does no more work and spends no more money than he has to. He studies the geology and tries to get as accurate an idea as possible of the distribution and manner of occurrence of his ore bodies, so as to save work and money in opening them up. Deliberately and intelligently he often defers looking for extensions of ore bodies until mining work has proceeded far enough to give him a good idea where to look.

Thus development work to a mine may be likened to food to an animal, if it is not supplied the mine will die of starvation. Just as an animal will die some time, even though it never suffers for want of food, so the mine will die some time even if it never suffers from want of development. A man does not concern himself much with a calculation of how much a horse will eat in its whole life, but rather with how much it requires every day. He does indeed take note whether his horse is young or old, strong or weak, and values him accordingly. He does the same with his mine, recognizing its stage of life and basing his expectation of its productive power on that recognition, but until it actually expires he never ceases developing it. He gives it the amount of development which he finds gives the best financial results, just as he gives his horse the amount and quality required to keep the horse in the best condition: that is, if he can afford it. If an owner cannot afford to develop his mine properly the mine suffers, just as his horse would suffer if he is not fed properly. In either case the question can be worked out, and is worked out in a practical way.

Thus for instance; the Anaconda mines at Butte, where for many years the question of exploration has been studied scientifically and comprehensively, yield about 120,000 tons of ore to each mile of development work; the Copper Queen at Bisbee, Arizona, about 50,000 tons per mile, the Chief Consolidated at Tintic, Utah, about 20,000 tons per mile; the iron mines of Michigan from 150,000 to 500,000 tons per mile, and so on. In each case mentioned, these mines or at least the districts in which they occur are forty years old, or more, and have been producing continuously on the same terms more or less but at an increasing rate. In the various instances mentioned the amount of ore blocked out in such a way as to be measurable varies between about six months and about five years production, and varies from time to time in each property. The satisfaction that comes to the owners from increased dis-

coveries is almost invariably an increased output, not the assurance of a longer life.

The difference of attitude which would be justified now in expecting continued life for many of these properties, compared to that which would have seemed to be justified twenty years ago is to be explained by the fact that many restrictions on the availability of ore deposits have been removed. This applies to large groups of mines. The steady improvement of the cyanide process of gold extraction has removed practically all the difficulties of working gold ore in the primary zone. The whole deposit is now profitable, not merely such part, often a small part, as might have been rendered available by the accident of one natural process having been superimposed upon another natural process. Similarly in lead, copper, silver and zinc, the oil flotation process and other improvements in concentration have removed difficulties that were then formidable. There is seldom any longer an absolute dependence on natural alterations and concentrations and in general a mineralized mass may be worked so long as it contains enough metal, quite regardless of the chemical combination in which it occurs.

Determination of Present Value from Known Factors.—If these questions can be answered it is easy to arrive at the value of the property as an investment. The general principle at the root of the matter is that the annual dividends must yield a good annual interest on the sum invested, and also permit a certain sum to be set aside each year, which, securely invested at compound interest, will repay the investment when dividends cease on the exhaustion of the mine.

If we take for an example the Miami Copper Company we shall find the facts approximately as follows:

The number of shares is 747,114. After five years of operation this concern had invested capital as follows:

For Mine Property	$1,535,000
For Mine Development	1,417,000
For Mine Construction of plants	3,059,000
For Mine Working capital (less current bills)	3,000,000
Total	$9,011,000

This represents a cost of say $12.00 a share.

The amount of ore remaining in the mine, of the kind on which operations were being conducted, was established at 18,000,000 tons, almost exactly 13 years life. According to five years experience the cost of producing copper was 10 cents a pound, the price received 15½ cents and the amount being produced annually 42,000,000 pounds. The investor believing these facts to be established might reason as follows:

The annual income might fluctuate but it would average almost exactly $3 a share a year for 13 years. His actual investment is $12 a

share. The amount required as net interest on this amount at 5% is 60 cents a year. The installment of capital required each year for thirteen years, to be put into a sinking fund and invested in gilt edge securities yielding 4% net annually, in order to restore the $12 invested at the end of that period, is 72 cents more. In other words the minimum return that would satisfy his investment at 5% interest and also return his principal in 13 years, is $1.32 per share or 11%. That is a general figure. Any business limited to a life of 13 years must pay 11% for that period or the investor will suffer a loss either of his principal or of the normal rate of interest which he has every right to expect.

But in this case the income promised was more than twice the amount required to cover his actual investment. In fact it was worth whatever amount the $3 per share per year would pay 11% on. This would be $27 per share; and this was actually the price of the stock in 1915, the year in which the record of the property stood as just described.

This matter will be referred to more at length in a following chapter.

CHAPTER III

NATURE AND USE OF CAPITAL

Discovery of ore element of its value—Inferior value of deferred earnings—Plants are seldom adequately designed in advance—Time required for launching an enterprise—Working capital—Length of life required to justify doubling the scale of operations—Example of Miami Copper Company—Earnings upon investments in plant tend to decrease—False inferences from occasional bonanza earnings. Capital and social theories—Acceleration of public opinion in certain directions during war times. Temporary measures sometimes have permanent effects—Capital lost or gained according to failure or success of enterprise—Its true measure is present value of property.

The price at which mine products are sold is not determined wholly by the cost of extracting them, but frequently by the difficulty of discovering them. Once found an ore-body is a prize, that is, if it is rich enough, and its value is established even if it lies in parts of the world remote from the centers of industry. It is obviously no test of the highest efficiency merely to make such a mine pay. The real test is to secure from it the greatest value possible. This problem involves not only the skill of the explorer and the miner, but also some consideration of the use and purposes of capital in ways not entirely obvious at first glance.

Deferred Payments

One of the first considerations of this nature is the plain fact that the promise of a dollar at some distant date is not as valuable as its immediate possession. This is just as true of incomes as of single payments. It requires little argument to convince a man that if he is to receive a total income of $10,000, he would be better off to get it in 10 years than in twenty, better off to get it in five years than in ten; still better to get it in hand at once. As a matter of fact, if interest on money is worth 5 per cent. a year, his $10,000 if paid in installments covering twenty years would be worth barely $6,000 at present; if he could get it in ten years it would be worth $7,500; in five years $8500; only if paid immediately would it be worth the full $10,000. If the same ultimate return should be spread over an indefinitely long period, say 100 years, his annual income would only be $100 and his capital, that is, the value of his possession, would only be such a sum as $100 would be fair interest on; a paltry $2000. These are surely not considerations merely for the banker or the

financier, but apply with equal or greater force to any one to whom the possession of goods, the acquisition of food, clothing and comforts, is a matter of importance. From this consideration it is a short step to perceive that an indefinitely long continuance of income which can never total more than a certain amount is not a good point but is distinctly a bad one, so bad that it would be excellent business to spend money to remedy it.

These considerations have a very wide application in the mining business. An ore-body, the discovery of which is valuable, is invariably limited in extent. If it were not limited, either its discovery would not be valuable or, a single discovery would serve all future purposes, which would be the same thing. Therefore, the miner attacks his deposit fully convinced that it contains only a certain quantity of valuable product; that it is worth while for him to secure and enjoy this product as soon as possible instead of waiting indefinitely for a slow dribble of output; and that his problem is to explore the mine intelligently so as to equip it in order that its working may afford the maximum satisfaction to the owners. This problem may be reasonably stated as that of creating the greatest *present value* for the property.

Present Value.—From this point of view, to my mind a just one, it will be found that the business enterprise based on a limited deposit will have a life of maximum desirability. Many writers on the economics of mining, such as H. C. Hoover, Ross E. Browne and H. L. Smyth, have given examples which seem to show that discovered ore, or even the entire mine, should theoretically be worked out in a very short time, say from three to nine years. This is, of course, provided that there are no exterior obstacles such as the danger of over-supplying markets, to prevent it. It appears, however, that the length of life which will create the maximum present value is inherently a variable depending on the relative value of the capital required and the total value of the product, upon the rate of annual profit earned upon the capital used in constructing and operating the plant, and upon the time required to put the plants in operation. Where the annual return on the invested capital is high the life should be short, but when that return diminishes toward an amount such as will be only interest on money the inducement to invest further capital for the purpose of hurrying output diminishes until it finally disappears altogether. When the return on capital is a mere interest rate the life of the enterprise has to be indefinitely long in order to justify the investment at all. At this point indeed the argument for the investment of further capital would be the same as would induce investment in government bonds—merely that one might have it to invest; and the effort and risk involved in initiating and managing an enterprise would go uncompensated. At this point of course there will be no inducement for enterprise and there will be none.

Fundamentals of Enterprise.—For several reasons that will be developed presently, these considerations promise to have greater weight in the mining business of the United States, perhaps in the world at large, than they have had in the past and it seems worth while to dwell upon them. As a foundation for the discussion let us first note the general conditions of a mining investment. It naturally includes as essential elements, opportunity, time, effort and cash, the value of all of which can of course be expressed in money.

Omitting from the question of opportunity the matter of ownership, we may put down as a minimum the occurrence of ores in paying amounts. It is a point quite often overlooked that there is an essential difference between merely knowing that an ore-body exists and having it so opened up that an output may be obtained from it. There are plenty of ores known to exist, from mere geological observation or inference, or from drilling or some other form of exploration. This information is absolutely essential to the initiation of an industrial investment and of course it must be paid for.

Delays.—Once the decision is made to follow up these discoveries a considerable time is necessary for opening up and equipping the mine, transportation system, mills and smelteries, in general terms the required plant. In making and carrying out the plans for all this work there is abundant opportunity for mistakes, delays and the deficiency of human comprehension and foresight. These are factors that are quite generally optimistically minimized. Why is it that if you plan a house to cost $3000, and let it on contract at that price that you find when it is finished that it has cost you $4500? Simply because neither you nor your contractor could think of everything that had to be done. When the contract is finished you find the house is not finished. This involves you both in additional expense and in unexpected delay; for you will certainly not be satisfied with an unfinished house, it will be nothing short of a desolate disappointment. If you cannot afford to go on with it you will have to confess it a failure. The next time you build a house, of course, you will be on your guard against these contingencies that you cannot foresee. You do not know exactly what the "unforeseeable" will turn out to be, but you know it is there.

This homely comparison illustrates an element of every engineering project. It is particularly worth remembering that the industrial arts, including mining, have been for a long time, and still are, in a state of evolution. There is no standardized plan or pattern of plant, operation or organization. Each new group of entrepreneurs may reasonably entertain hopes of improving upon their predecessors, in some respects at least, and in any event they invariably expect to make special adjustments for their own special conditions. Nothing is more common than to change plans even after actual construction has begun, even on large

scale plants; indeed sometimes the changes take the radical form of increasing the whole scale of operations, perhaps to take advantage of further developments of ore or to provide for working additional property. Thus while American engineering projects are generally carried out energetically and promptly and on a large scale, it is quite imaginary to count upon them as being products either of invincible skill or of unerring judgment. They invariably cost more time and money than is foreseen and planned for. The large group of western mines known as the Porphyry Coppers is an excellent illustration of all these points. The time required to get a plant running from the moment of initiation was between three and seven years. The Inspiration Copper Company is of all these no doubt the greatest engineering success, but it is at the same time an example of all these causes of delay. Before it was finally launched as a going concern its properties were increased by various consolidations, its plants were designed for different outputs, and construction was interrupted in order to make a radical change in milling methods—from water concentration to oil flotation.

Time Required for Completion.—Whatever may be said of starting a new plant may also be said of making radical additions to an old one; indeed, unless the original plant was especially designed to be added to, the difficulties are actually greater, for the operating plants are quite apt to get in the way of the additions and to compel the engineers of the enlarged plant to put up with a scheme bound to be in some respects antiquated and unsatisfactory.

Thus it seems that to change the scale of a mining operation is a matter requiring from three to seven years. We might approximate it at four years. Theoretically such a requirement seems unreasonable, but if we are to deal with the business as a practical matter of finance it is far safer to count upon the actualities of experience than upon the calculations of theory. Of course not all plants require the same amount of time. The small and rude plants required for the shallow zinc mines of Southwest Missouri and Oklahoma may be built and started in a few months. But such plants are not only unrepresentative of the average conditions in the mining business but they are, after all, only partial installations. The general tendency is toward elaboration of method and comprehensiveness of plan. If the operators in the Miami district contemplate their business in the aggregate, say as a matter of establishing an output of 100,000 tons of spelter a year, they will perceive that this is no problem of starting to dig ore from a forty acre lease, but of exploring thousands of acres of land and of building smelteries and power plants. Such an operation would probably require the four years which we find has been required to start the average western copper mine. We may fairly assume that mines which may be quickly started, or quickly placed upon a new operating basis, are not really

complete industrial units but merely minor parts of a broader scheme already running. We might almost say they are not really mines, but *stopes*.

Here then we find an abrupt practical limitation to theoretical calculations of present values. If indeed a mine could be worked out to advantage in three years after a plant is running it is at least an embarrassment to have to wait four years before it can be started.

Almost the same observations apply to the cost of plants as to the time required. A priori calculations are seldom adequate. The safest estimate will be the one based on the total expenditures that have been required for a similar plant.

Working Capital.—The working capital is something that it is easy to forget altogether. The amount required is usually equal to the cost of operating for between six months and a year. Thus a company which expends $500,000 a month, will need from $3,000,000 to $6,000,000 working capital. Let us take as an example the Miami Copper Company again. We found that concern in 1915 producing about 42,000,000 pounds a year. Its capital accounts stood as follows:

Mine property	$1,535,000
Mine development	1,417,000
Construction	3,059,000
Working capital	3,000,000
Total	$9,011,000

If at that time it had been considered desirable to double this output from the same property we might estimate that the scheme would not have been completed before 1919 and the capital account for an output of 84,000,000 pounds would have stood about as follows:

Mine property	$1,535,000
Mine development	2,834,000
Construction	6,118,000
Working capital	6,000,000
Total capital required	$16,487,000

Here we have an increase of capital amounting to nearly $7,500,000. In 1915 the normal earnings were about $2,250,000 a year and if the operations had been merely maintained on the same scale in the four years required for increasing the scale of operations the company might have paid $9,000,000 to its stockholders; but if the enlargement were to be paid out of earnings, it could only have paid $1,500,000 to the stockholders.

What length of life would be required to justify this course?

We have figured out (see preceding chapter) that in 1915 with a life of 13 years the stock was worth $27 a share. It is plain that the increase we are arguing about would not benefit the stockholders unless it would increase the present value of the stock, that is, the value in 1915. Of course any such increase would have to be figured into it from the expectation of increased dividends to be obtained as the result of the project. It is easy to see how this would work out from the standard calculations of the value of a series of installments of income (see Chapter V on Partial and Complete Costs). The four installments of reduced income totaling $1,500,000 equals 50 cents a share for four years. The expectation of these payments was worth in 1915 $1.75 per share. In 1919, the company would go on a basis of $6 a share for four and one-half years—at which time the mine would be exhausted. By doubling the output we have not shortened the life of the mine by one-half, but merely from 13 years to eight and one-half years. This is the stumbling block to increasing value by increasing output; it has to be paid for by delay in receiving earnings. In 1919 the value of $6 a share for four and one-half years would be about $23. But this was not the value of these installments in 1915. Nobody will pay $23 for $23 to be paid four years hence. One would lose money unless he discounted the sum by an amount which would constitute interest on his payment for those four years. The actual value in 1915 would be about $19.16 to which would be added $1.75, the present value of the four minor installments, making a total value of $20.91. But the stock was worth on the former basis $27.

There are many variations that could be introduced into such computations. For instance, we might take into consideration the final liquidation of the working capital which is an asset that would be worth loss to the stock on the long life basis than on the shortened life basis. But to go into such niceties is wasted time in view of the already obvious fact that the increased scale of operations is not warranted, but would involve less and wasted effort, and would be, in short, an engineering and financial blunder of the first magnitude. But there must be some volume of ore and some length of life that would justify doubling the output.

We have been figuring on a total of 18,000,000 tons equivalent to 13 years life at 1,400,000 tons a year. Let us calculate the present value on that basis and on the doubled basis beginning in 1915 and assuming longer lives for both projects.

Scale 1,400,000 Tons a Year			Scale 2,800,000 Tons a Year with 4 Years Delay	
Tons	Life	Value per share	Life	Value, 1915
21,000,000	15	$30	9½	$1.75 plus $23.00 = $24.75
28,000,000	20	36	12	1.75 plus 31.55 = 33.30
35,000,000	25	40.50	14½	1.75 plus 37.75 = 40.50
42,000,000	30	44.20	17	1.75 plus 45.00 = 46.75

Thus we perceive that it is not until the volume of ore is doubled will it pay to double the scale of operations. The inference is that the Miami mine was skillfully exploited in the first place.

These calculations must not be confused with other factors which might (and, as a matter of fact, do) enter into the situation. The output of the mine has actually been increased by one-half without any corresponding increase of plant cost, but merely on the strength of minor alterations and adjustments. This fact does not enter into my argument, for the fact that such adjustments could be made means nothing more than that the capabilities of the plant had not been fully worked out and utilized. Any increase of output, without additional expense for construction, is pure gain. Anything short of running a plant at full capacity is uneconomical. The shortening of the life of a mine by such means, that is, without the use of additional capital, is so obviously advantageous that any discussion of the arithmetic of it seems superfluous.

Earnings upon Plant Investments.—The real point of this discussion remains to be brought out. It will be noticed that the earning power of the capital invested in plant and working capital on the Miami ores is 30 per cent. per year. The minimum life required to return this capital with 5 per cent. interest is 3.8 years. We have seen that it will not pay to double the scale of operations unless the life on this scale exceeds 25 years. At a smaller increase of capacity, say 25 per cent., we find that the present value will be increased slightly at a life of less than 25 years. It is plain that when the capital return is 30 per cent. and the time required for initiating an enterprise is four years, the scale of operations to give the maximum value should be such as will give a life of between 20 and 25 years.

A consideration of a variety of factors that might be introduced, such as the possibility of initiating plants in a shorter period than four years, would involve us in almost interminable arithmetic and would probably be tiresome without adding much to the clarity of the subject. It seems already evident that the time required for plant installations is an important element in the problem of the intelligent use of capital not only in mining but in industry in general, and that where the return on capital is high and the warrantable life of an enterprise short the interference of delay becomes proportionately greater. Thus if the earnings upon capital are 100 per cent., if it requires four years to start a plant and if the capital required is in use an average of one-half the time required for its investment, it is plainly impossible to see any merit in an enterprise that will run less than two years after the plant is started. It is rare indeed that earnings will be so large, although there have been instances where they have been much greater. For example the Goldfield Consolidated mining and milling plant probably cost about $2,000,000 in the aggregate, and required 2½ years for completion, but it immediately

began to earn profits at the rate of $6,000,000 or $7,000,000 a year. A single year's operation would be a recompense for both the investment, the time and the effort. But such instances are merely spectacular accidents which are less and less likely to be repeated. The whole tendency of the mining industry is toward less dependence upon the discovery of bonanzas and more dependence upon capital and sustained industrial effort. The number of mining enterprises in this country that are rich enough to warrant an operating life of less than five years would probably constitute only a minute fraction of the industry, certainly not worth public attention. There are of course many mines in the country where the earnings on the capital invested are still handsome, say from 25 to 50 per cent., but the largest mining enterprises are already far below that figure. In the case of the United States Steel Corporation the capital invested averaged before the war no less than $140 per ton of finished product sold each year and the earnings only $8, or less than 6 per cent. If money is worth 5 per cent. interest the shortest justifiable life of such an investment is more than 40 years. If the earnings on capital are 10 per cent. the shortest justifiable life will be 15 years. It may be worth while to repeat for the sake of emphasis, that the shortest justifiable life is that which will merely return the capital with such interest as might be obtained merely by lending the money on good security. When we come to take account of the difficulty of guarding against changes of failure such as lie in the overestimate of the ore supply, underestimate of cost, unfavorable changes in prices, or in absolute accidents, it seems venturesome to count upon a return as low as 10 per cent. as a safe margin for investment. In order to justify it we should have to count on exterior factors, such as a probability that the business would continue to expand indefinitely instead of being limited to an exhaustible deposit. Perhaps we shall not be far astray if we assert that the bulk of mining enterprises are based upon a return of between 10 and 50 per cent. on the capital required for development, plant and working capital; that these returns vary according to the relative abundance of the materials dealt with, and that the higher returns are obtainable only upon bonanza deposits in which the mere discovery is a matter of capital importance.

Bonanza Earnings.—These statements are liable to be misunderstood unless the basis for them is thoroughly explained. It is possible for one intent upon showing the extraordinary profits of the mines to take for an example some notable bonanza and explain to the public that its great earnings come from practically nothing. This is often done for two diametrically opposite purposes. On the one hand the stock promoter uses these figures to tempt speculation; on the other hand theorists on social systems use them as examples to illustrate the inequalities and injustices of the distribution of wealth which lie in "capitalism." Both

representations are apt to be full of the errors of little knowledge, which Shakspeare describes as a "dangerous thing." Let us take as an illustration the most remarkable mining bonanza of recent times, the United Verde Extension copper mine.

This property was discovered by the present company at a cost of about $275,000. It immediately began shipping ore running more than 25 per cent. copper and within three years under war prices it was earning at the rate of $12,000,000 a year. These facts sound exceedingly extravagant; but when we come to examine them in terms of the normal conduct of business we shall find modifications at once.

In the first place, the expenditure of $275,000 was not really all the money put into this discovery. It was merely the amount required to put through the fortunate and decisive chapter of it, which was the reorganization and re-financing of an existing company. Exploration had previously been carried on for many years without success and large sums of money, I do not know how much, but certainly many hundred thousand dollars, were spent. The work and money thus spent were not lost but pointed the way to the ultimate success. Thus the actual cost of the discovery must actually have been near $1,000,000 instead of $275,000 as usually stated. Furthermore, the money spent by this company and on this property was only a small part of the amount spent on account of this very bonanza; for as soon as this discovery was made other explorations were undertaken right and left, in part by the very people interested in the Verde Extension, and millions were put in without resulting in the discovery of even a dollar's worth of ore. The real cost of the discovery, therefore, was not $275,000 at all but several millions. If it were a matter of importance the real amount could be determined with fair accuracy.

The next modification is that the apparent profits were for a time doubled by war prices.

A further modification is that the sums stated as earnings have not been paid to the stockholders, but only a quarter of them. They never will be paid, for they have been used in the construction of a plant, the development of the mine, for workings capital and for war taxes. If there had been no war prices the earnings would have been, in 1916, 1917 and 1918, so much less that the dividends would have been certainly less than half of the $6,667,500 actually paid.

Borrowed Capital.—But the consideration that is really obscure to those who do not take the trouble to reason it out is the fact that whatever earnings that have gone to the stockholders really came from borrowed capital. The new bonanza mine had no equipment of its own to enable it to put copper on the market. Railroads have been built for other mines by which smelteries, also built for other mines, could be reached. The owners of the United Verde Extension had to pay a toll

out of the richest of its ores for the use of that capital: it paid in the form of profit on freight and treatment. To ship those richest ores was only a fortunate and temporary expedient. The enterprise needed a plant of its own in spite of all the assistance of this kind that it could negotiate for. The construction of a smeltery, of a tunnel and railroad to connect it with the mine, of shafts, machinery, living accommodations for employee (these being nothing short of two townsites, one at the mine, the other at the smeltery), the purchase of land and the creation of a working capital have actually absorbed some $12,000,000 to $15,000,000. If the work had been done under pre-war conditions these requirements would have been smaller, by perhaps a third. But the mine cannot continue to ship the extraordinary ores that were obtained in these first years, and its earnings certainly will not average as much as 50 per cent. on the capital required to establish and operate it.

The individuals who put through the reorganization of this company reaped extraordinary profits. They drew a capital prize in the lottery of nature by paying for only one of the tickets. It is equally true that they used this prize with skill and acumen and out of it built up an extensive industry by using a part of their prize as capital. It is a first rate example of adventure and success; the kind of enterprise that has been the very life of the mining industry, keeping alive the desire for fresh efforts, and lending zest and even romance to the development of the country. There are certain elements in our national situation which make it worth while to inquire whether this sort of enterprise is to continue freely or whether it is to be curtailed and discouraged. The importance of this question has been accentuated by the war through the increase of taxation that is the invariable concomitant of wars.

There is no question that the mining industry should pay its full share to support the government and every national enterprise in proportion to its income and profits. But it is exposed to the danger of confiscation of capital under the guise of "income" and "excess profits." The manner in which this may be done may readily be gathered from the preceding discussion and examples. The revenue law of 1918 was passed at the very time when the wave of enhanced profits due to high war prices was rapidly receding. Costs were rising by leaps and bounds and prices were either fixed or falling; profits were really not much above normal and promised soon to become sub-normal. The law carried a provision for taxing "excess profits" up to as much as 80 per cent., and the question of the amount of profit was to be determined not by the relation of the war earnings on an ounce of gold or a pound of copper to the normal earnings on an ounce of gold or a pound of copper, but was to be fixed by the nominal capital of the enterprise. For instance there was acute danger that according to this law the capital of the United Verde Extension would be put down at fifty cents a share, 10 per cent. allowed on this value

for normal profits and the remainder taxed 80 per cent. as "excess profits." In the meantime many persons had bought this stock at over $40 a share on an expectation of normal profits, that is, not counting upon war prices at all, and the actual profits were little, if any, above what might have been earned in ordinary times. According to the plan of the law 80 per cent. of the earnings would be swept away. On these terms four-fifths of the capital of actual investors would be confiscated. There were two questions that might logically be considered (1) what was the normal profit of the product of this industry? (2) what was the capital in this industry?

Before proceeding with the second point it may be reasonable to interject that an excess profit tax on real excess profits, as a war measure, could hardly be objected to. It will be shown elsewhere in this volume that the United Verde Extension might under average pre-war conditions expect to make 10 cents profit per pound of copper. Now if it were making during the war 20 cents it would be not unreasonable to say that it was making 10 cents "excess profits." A tax of 80 per cent. of that amount even in addition to other ordinary income taxes would not be confiscation. But the question would not necessarily be disposed of even at that point for it would still be necessary to scrutinize the receipts and expenditures of all mines according to a uniform principle in order to fix the amount of profit fairly. There would, however, be no objection to the theory if it could be properly applied.

It is hardly to be expected that the American nation will be influenced permanently by the psychology of a war period. There is no immediate prospect of more wars in the future than there have been in the past. Since the Revolution this country has been engaged in wars of greater or less importance about 7 per cent. of the time, and its ordinary disposition is to dismiss the question of war as an abnormal and improbable contingency. Nevertheless, steps are taken during these occasional wars that have unexpected results in times of peace. A tariff to provide war revenue may be converted into "protection," a policy which may or may not merely favor some industries at the expense of other industries. A temporary stopping of brewing and distilling has been converted by war psychology into permanent and constitutional prohibition much sooner than would have been the case normally. Similarly the marked increase of taxation on incomes, as a war measure, may develop, or degenerate, into a deliberate and sustained attack on capital. Government administration of railroads as a temporary expedient, may be the chrysalis of government ownership. The net result may be to multiply the number of government employees, multiply the weight of the machinery of government and substitute for the independence of individual initiative a general dependence upon government employment. There are many who regard all these tendencies as desirable, indeed look upon any-

thing that can secure a majority of votes as not only desirable but sacred. It is hardly worthwhile to have fixed opinions as to the merits of such tendencies; it is more to the point to discern if possible how powerful they are and what forces lie behind them. To make such an analysis is entirely beyond the scope of this discussion, but it seems as if we cannot be far wrong in drawing a general conclusion that the mainspring of most of the tendencies of social, political, and economic legislation is faith in cooperative effort as against individual effort, and doubt as to whether this cooperative effort may properly be left to individual owners. The efficiency of great corporations has been demonstrated in many industries; would not still greater corporations, even one all embracing corporation, the government itself, be still more efficient? Would not such an institution automatically make us all comfortable and relieve us of the terrors of making a living?

Private Ownership a Fundamental Law.—But this idea is still only a theory and will undoubtedly remain so. It is easy to see how the cooperative or integrating movement will reach absolute limits, in the form of intricacies of detail which would be beyond the power of any corporation to master. When the tendency to integration is forced by its momentum beyond its proper boundary it is bound to be overcome by the reaction of disintegration. The right of private ownership of property is still recognized by the fundamental law of the land. It is a natural desire of every man to have something of his own which he can alter, dispose of, or lend to suit his own whim. Whenever the theory of government interference goes far enough to deny the whims of a large enough number of people, it will meet effective resistance. Thus far it has been easy to draw some distinction between aggregates of "capital," generally typified in the name of some individual whom magazine writers have made as mythical as Hercules or Theseus, and private property. No person with a spark of ambition or initiative wishes to deny himself the right of owning property and increasing it. The world is not ruled by the passive and timid no matter how greatly they may preponderate in numbers; it is ruled by the aspiring and energetic. Now the mines of the country are not owned by a few rich and decadent beneficiaries of privilege but by a huge army of stockholders, investors great and small, whose capital is, by overwhelming preponderance, the fruit of their own efforts and their own virtues; of frugality, industry, enterprise and ability. These people have a decided interest in holding their capital intact and not having it reduced or dissipated by ignorant, perhaps malicious, taxation of "income." This might in the minds of theorists, whose number is apparently increasing, be a convenient way of meeting the increased expenses of the government. These expenses are to be permanently increased not only by the interest on war debts, but by the growth of government bureaus which has been greatly stimulated by

the war; and by a general expansion of the policy of the government which it will be difficult, no doubt, to nullify.

Capital is Present Value.—What, then, is the capital of mines? There appears to be no sure way of fixing capital, or of distinguishing it sharply from profits. Some may be disposed to argue that capital is the actual amount of money invested in a given project. This does not seem to fit the case except momentarily. When an enterprise is launched the amount of money put into it is, of course, the amount upon which a return is expected, but it is always a mere accident if the return is just equal to the amount required. It is far more likely to be either below or above that amount; if below, a portion of the investment is lost, because the enterprise does not yield an amount sufficient to return it to the owners; if above, a gain is made because the yield is greater than the amount required to return the investment. In one case the capital diminishes, in the other it increases, in neither case does it remain stationary.

If an investment is disappointing no amount of argument will restore the capital, therefore everyone must admit that it involves a loss of capital. If we are to argue that the capital in a successful enterprise does not increase then we shall have to look forward to the extinction of all capital, for it is self-evident that if some enterprises lose capital and none gain it, the process of investment must be one of destruction.

Again, what is the amount invested? Must it be money drawn from a bank or can it be some other form of value? Take for instance a mine; one party contributes $1,000,000 in actual money for equipment, another contributes a tract of land, on which say $10,000 has actually been spent, but which nevertheless is accepted by the first party at a valuation of $2,000,000. That the transaction is made in good faith is proved by the fact that the party which contributes all the money is satisfied with only one-third of the property. In this case, a very frequent one, is the amount invested, the $1,010,000 which we may trace to actual money transfers or is it the $3,000,000 agreed upon as the basis of the property transfer? My assumption is that the investment is the latter sum. I would assume further that this sum is the capital put into the enterprise at the time the bargain is made, but that it is not necessarily a permanent measure of the capital any more than the $10,000 in money put into the land was a final value of the value of the land.

This train of argument leads to the conclusion that, if we are to admit the existence of capital at all, we can only describe it as so much value. We must ignore the origin of that value and devote our attention to the practical matter of how to measure it. I believe this conclusion is one which has been upheld and will continue to be upheld by the courts as well as by financiers. It seems utterly absurd to argue that capital can be limited by the mere process of setting down certain figures. It is

equally out of the question to attach any commercial significance to how much capital could be credited to an enterprise or to an individual at some past date. The fact that a rich man of today, was a penniless boy fifty years ago, has no bearing whatever on the amount of capital he may own. Similarly a mine yielding $1,000,000 a year is surely an asset, and that asset is capital, without any regard to the fact that it may have been started by prospectors by dint of manual labor and absolutely without a bank account.

As to the process of establishing value, I have always argued that it must be traced to commercial transactions. We cannot attribute any theoretical value, for instance, to the metal lead. There might be, perhaps, some theoretical figures worked out for it, based, let us say, on its relative abundance compared with other metals, or some such considerations, but nobody would pay any attention to them. The value of lead is always established by its price in the open market. The value of a lead mine must rest on that price, and has to be figured from the amount that can be marketed, the cost of production and the time required to complete the operation. If these additional factors (quantity, cost and time) are involved in uncertainty, as they usually are, it is obvious that the valuation of the mine is a much more intricate and less reliable matter than that of the metal. As a matter of fact grave mistakes are made. Properties are often accepted by the public at high valuations but turn out finally to be worthless.

This is the argument for not accepting stock market quotations for the value of mining companies; although we must admit that in the majority of cases these quotations do give a reasonable approximation of the values. But we must remember that mines are not staples like the metals they produce and that market quotations upon them are of a different order from quotations on staples. Thus lead in a warehouse is always marketable. It is as good as any other lead. Its price varies between certain limits, of course, but the market value, whatever it is, is always there. But there is no such certitude or permanence about the stock of the mine. Today it may be in high favor; five years from now it may be worth twice as much, or nothing at all, and the quotations bear no definite relation to the price of the metal, but are influenced strongly, often decisively, by other factors.

Again, we can never be certain that the valuation of stocks by market quotation represents the same action in all cases. Many properties are not on the market at all. Of those actually before the public, some may be in high esteem, skillfully advertised and distributed among a large number of holders; others may be scarcely noticed, with few holders, few transfers, and the market may be merely nominal. It is conceivable that the highly advertised stock might bring twice the price of the obscure one, even though both have the same actual merit.

I think these considerations are generally conceded to be convincing

reasons for subjecting the valuation of mines to a searching and independent review every time such property becomes the object of any important transaction. I think the government should recognize this fact in its dealings with mines. In former times those dealings were from a financial point of view, of slight importance, but under present conditions the settlement of taxes is for prosperous concerns, a transaction of the first order. It follows that it is highly desirable for the government not only to permit but to encourage a rational method of valuation, which can be applied at any time at the instance of either party.

If the purpose of a government is not to promote fair play among its citizens, then it must be prepared to exercise its forces regardless of fair play. This does not sound well, for the next inference is that if the organized powers of the government are not necessarily to be used to secure justice, they may be used for oppression. An attitude of this kind, therefore, on the part of the government, is one tenable only as an excuse for a temporary confusion, and not as a real policy. It follows as a practical conclusion that the government must adopt a logical and equitable theory of distinguishing capital from profit.

My conception of such a theory may be summarized as follows:

1. The capital is the present value that could be realized from the liquidation of an enterprise, through normal commercial transactions.

2. Profit is a fair interest upon the capital.

3. In the case of a property like a mine, in which a profit can be made only by using up its physical resources, income is never wholly profit. In the case of an unprofitable enterprise, the income is merely a partial return of money actually invested. In the case of a profitable enterprise it is partly capital and partly a return on that capital.

When such a property is short-lived the proportion of capital required each year is large. As the length of life increases, the annual installment of capital diminishes—thus a property which is to be liquidated in three annual installments requires an annual return of capital equal to more than 31 per cent. of the total value, while one that is to be liquidated in thirty annual installments requires a return of only 2 per cent. Let us suppose that in each case, the income is $1000, and that in each case the interest rate is 5 per cent. In the three year property the present value is approximately $2790; the annual income is $930 principal and $70 interest or profit. In the case of the thirty year property the present value is $15,000, and the income is $250 principal and $750 profit. In the first case the capital return required is 93 per cent. of the total income, in the second only 25 per cent. (These figures are only approximate but they illustrate the point.)

From this it is clear that as a matter of calculating income tax the question of the proportion of profit is more a question of expected life than of anything else. When the life is unlimited the capital installment is zero and all income is profit.

CHAPTER IV

FACTORS GOVERNING VARIATIONS OF COST

WHAT THE COST CONSISTS OF—FACTORS DIVIDED INTO EXTERNAL AND INTERNAL GROUPS —EXTERNAL FACTORS: LABOR SUPPLIES, CLIMATE, TRANSPORTATION, WATER—INTERNAL FACTORS: OREBODIES, ATTITUDE, CONCENTRATING QUALITIES, SMELTING QUALITIES—MINING AND METALLURGICAL LOSSES AND THEIR EFFECTS UPON COSTS —ELEMENTS OF A COMPLETE COST STATEMENT—CHARACTER OF ACTUAL REPORTS —MANAGEMENT—HOW RICH MINES ARE MORE COSTLY TO OPERATE THAN LOW-GRADE MINES—HOOVER'S THEOREM ON THE RATIO OF TREATMENT CAPACITY TO ORE RESERVES—ECONOMY AND SPEED—PRIVATE MANAGEMENT AND PUBLIC INTEREST.

IT is necessary first to define what we mean by the cost of mining. It may be divided into three parts:

(*A*) The use of capital in acquiring the opportunity to mine, *i.e.*, ownership of ground, or leases. Since the value of this kind of property is only a speculative anticipation of profits to be won by operating, and is moreover often appraised in a fanciful or even dishonest way, I prefer to leave this element out of the discussion. I am quite aware, however, that as a matter of practical finance this cost must generally be considered.

(*B*) The use of capital for equipping and developing a mine, for providing mills and smelters.

(*C*) Current operating costs, including taxes, the maintenance of company organization, insurance, litigation, etc.

For present purposes I select *B* and *C* and my defintion is: The complete cost of developing, equipping, and working out a mine, allowing interest on the capital required for these purposes until it is returned in dividends.

As any one with the most meager acquaintance with the subject must know, the cost of mining at different places is subject to great variations. I am not sure that the factors governing these variations have been fully stated.

A general division may be made between factors that are external or fortuitous and those introduced by the internal make up of the orebodies. It is evident that no quality in the deposit itself can influence any of the following groups of conditions:

(1) The cost and quality of labor and supplies.

(2) The climate, altitude, or distance from populous centers.

(3) The hardness of surrounding rocks, the amount of water, the depth from surface.

(4) The facilities and cost of transportation to milling or smelting centers or markets.

All of the above conditions vary from place to place and introduce differences in the cost of mining, though not such great differences (as will be shown later) are as caused by the inherent qualities of the orebodies themselves.

Cost of Labor and Supplies.—The wages in the mines of the United States varied in 1908 between 20 and 60 cents an hour, now perhaps between $0.40 and $1.20 per hour. Usually the difference is partly made up by the varying efficiency of the men. Where wages are low the supply of labor is meager, the best men are constantly leaving for more favorable localities those employed are not subject to the spur of keen competition, and the results are constantly disappointing. On the other hand, where wages are high, the most ambitions and intelligent men are attracted and they compete with each other for the places.

It is hard to fix any figure for the compensation thus effected, but it would perhaps be safe to say that one-half of the apparent difference is made up. Some authorities will say it is nearly all made up. Messrs. Taylor & Brunton tell me that in operating sampling mills at Cripple Creek Colo., where the wages are 40 cents an hour, and at Salt Lake City, where the wages are 25 cents an hour, there is but little difference in the labor cost per ton sampled. If we assume that while the difference in wages is represented by 20 and 60 and the difference in cost efficiency by 40 and 60 (or 70 and 100), we find that the variation in labor cost is only about 30 per cent, from the maximum. Since the labor accounts generally are about 60 per cent.of the total current cost of mining, differences in wages are not likely to account for a variation of more than 18 per cent.[1]

In the world at large, outside of the United States, there may be instances where the differences in wages are more important than within the United States. Nevertheless, in the few important mining districts

[1] The experience of the war period has demonstrated a modification of this generalization. It would be better stated that high wages do not cause high costs *under competitive labor conditions.* When the demand for labor exceeds the supply workmen are merely tempted to change from one industry into another with which they are not familiar and in which their efficiency is at first necessarily less. The depletion of the labor in the first industry soon causes an effort to tempt men back again at still higher wages. Finally large groups of men become careless of their jobs, the more so, perhaps, the higher the pay, certainly in some proportion to the ease with which a new job may be obtained. They will frequently change about for trivial reasons such as curiosity to try something new, desire to see the country or to show their independence. As the numbers of such a group increases their example becomes fashionable and demoralizes the standards of more conservative men. Without any concerted plan therefore efficiency diminishes, production diminishes; the demand for output is further than ever from being satisfied, the economic unbalance is intensified and costs increase without ascertainable limit.

of which I have any knowledge, such as the Transvaal, India, and Mexico, where native labor is employed very largely at very low rates, it is well known that the costs are not lower than in the United States for similar work. It appears that where labor is very low there is little or no acquaintance with machinery and the performance per man is correspondingly low. Where large numbers of natives, ignorant of all civilized mechanical appliances, are employed at a large plant, they must be supervised by white men who do little actual work and get wages higher than those they receive at home.

In the English-speaking countries where mining is an important industry, it may be said that the conditions as regards labor are almost identical with those of the United States. It does not appear probable therefore, that my conclusions regarding the variations caused by wages in the United States need to be essentially changed when applied to the important producing centers of the world at large. Extreme variations must be confined largely to isolated and abnormal localities.

The cost of supplies affects the cost directly. The important supplies are fuel, timber, explosives, steel, and tools. In the United States the price of these commodities does not vary enormously among the important mining centers, certainly not much more than 50 per cent. from the maximum. Since the collective cost of the various supplies is rarely more than 20 per cent. of the total current mining cost, a variation of 50 per cent. in the price will produce a difference of only 10 per cent. in that cost.

The cost of supplies in the world at large is apparently subject to about the same degree of difference as the cost of labor, but it is to be remarked that in any country, such as India and South Africa, where the price of labor is nominally low, the cost of supplies is usually distinctly higher than in the United States. In the Transvaal for instance, Ross E. Browne estimates that the additional cost of supplies as compared with California accounts for approximately 10 per cent. of the total cost of mining.

Underground Conditions.—The hardness of the rock is likewise a comparatively unimportant factor. In any case the hardness affects only one division of the underground work; namely, breaking the ground. The stability of the ground is much more important than the hardness. Timbering is often an important item.

Increase in depth adds something to the cost of hoisting and pumping, but it is to be remembered in this connection that if a mine is only 100 ft. deep, machinery must be provided for these purposes and a complement of men employed to operate it. As depth increases, the only change that comes in is the requirement of heavier machinery and additional power. The increase of cost, therefore, is far from being proportional to the depth. One consequence of extreme depth that might easily be overlooked is the daily cost of transporting the men to and

from their working places. In the case of the Calumet & Hecla, the hoisting engines are in use two hours each shift in lowering the men and hoisting them out again. Not only does this represent a considerable expense in itself for mere hoisting, but the greater part of the time of the workmen for this period is lost to the company.

The temperature of underground workings often becomes a matter of considerable importance. A high temperature may be caused by the climate, or by great depth, or by the presence of hot waters or heat-producing chemicals. It is only in the last case that the heat can be called an inherent quality of the orebody itself. There have been cases of such high temperatures in mines as almost to prevent working altogether, but ordinarily temperatures of 80 or 90°F. are about the limit reached in important mines. Such temperatures affect the energies of the men adversely, although men grow accustomed to them and suffer no ill consequences in the way of health. The importance of this factor is extremely difficult to appraise in figures, although in the case of the Calumet & Hecla, Anaconda, and United Verde, to cite conspicuous examples, the loss of effectiveness in labor through this cause must represent annually a very large sum.

These remarks are intended to apply only to underground mines. Where the work is done wholly upon the surface, the facilities for working are so much superior that mines of this character must be considered separately.

Climate, Altitude, and Population.—The influence of climate, though indirect, is powerul through its effect on human life and effort. Sometimes in places where there is an excessive rainfall or excessive heat or unhealthful conditions, the effect may be to limit the scope of operations. For instance, in Ecuador, South America, a plant has been running 35 years, but on account of the climatic influences it was for 30 of those years impossible to secure more than about 60 effective miners, although the economical management of the property required the employment of several times as many.

Excessive altitude, and great distance from lines of transportation, place similar limitations upon enterprise. Where several factors of this kind are present at the same locality, the aggregate effect is to place almost unsurmountable difficulties in the way of successful operations, but as a general rule in places where important mines have been discovered, most of these difficulties have been overcome. For instance, in the San Juan region of Colorado, and in the Cerro de Pasco in Peru adequate transportation facilities have been provided and the only adverse conditions still remaining are the altitude and disagreeable climate which have in both instances a pronounced ill effect upon the performance of the labor.

Transportation and Marketing the Product.—Transportation facilities may be described as adequate when they are sufficient to handle the

output of a mine and to deliver with promptness the necessary supplies; but adequacy in this sense does not mean cheapness. Transportation is in very many cases one of the most vital elements in the cost of mining. This is particularly the case when the products have to be shipped considerable distances. In the case of coal and iron it is a matter of common knowledge that transportation is often the all important factor, and even in the case of precious metals sometimes the cost of transportation to mills and smelters equals, if it does not exceed, the cost of actual mining. The intimate bearing of this fact upon mining methods and results aside from the mere question of transportation cost in themselves will be described later on.

Another factor that is often of considerable importance is the commercial matter of marketing the products. This is sometimes done by contracts with selling agencies; and sometimes by the company itself. In either case there is to be taken into consideration, in addition to the cost of marketing, the success achieved in disposing of satisfactory quantities of the product. It is in this respect particularly that the cost of mining may be greatly influenced by this factor in determining the volume of operations.

Coincidence of External Factors.—One would scarcely expect that these various factors would move in unison, *i.e.*, that they should all be equally bad in one place and equally good in another. So far as the natural conditions such as rock hardness, depth, and amount of water to be pumped are concerned, it is indeed extremely unusual that such factors are at a given place at either extreme; but it must not be forgotten that the remaining external factors have their effect through the efforts of man himself. If the mine is situated far from populous centers the reason is apt to be that the climate or the altitude is unfavorable. This generally means that labor is dear and inefficient, supplies costly, transportation difficult and expensive. These factors are likely, therefore, to be affected together, and if one is favorable they are all likely to be favorable and *vice versa*.

The sum total of cost variations that may be due to the coincidence of these external factors is therefore considerable and is sufficient to prevent the working of abundant yet valuable products such as coal, iron ore, or salt at places where these conditions are all bad. It may be said that the above factors are those which as a rule govern the variations in the cost of low-priced and bulky mineral products.

Internal Factors.—The internal factors are: (1) The size and attitude of the orebodies; (2) the relation the valuable material bears to the enclosing gangue or material; (3) the problems involved in metallurgical treatment.

These factors introduce immense differences of cost. For instance, in gold mining we find that the Alaska-Treadwell has mined, treated, and mar-

keted its ore for $1.48 per ton, while the Camp Bird in Colorado producing gold ore subjected to the same process costs $12.50 per ton. The wages are the same, the rock is of the same hardness, the water is no problem in either case, the method of mining even is practically the same. The general management of the Treadwell is probably more economical than that of the Camp Bird, but the difference is not to be laid to this score. The difference comes in the factors mentioned above and those factors are so important that they are worth a more extended consideration.

If we have a body of homogeneous material more than four feet thick and continuous, it is evident that the mine openings can be made very largely, if not wholly, in the stuff to be extracted. Practically every blow struck produces ore. But reduce the thickness to be mined to one foot and we are at once confronted with the necessity of taking out three feet of worthless material for one foot that is valuable, besides having to take pains to keep them separate. Here we introduce at once an enormous proportion of wasted expense that must be borne by the valuable ore. Now break the continuity of the deposit and it is evident that openings have to be made entirely through waste material merely to find and open up the scattered bodies. This evidently increases the cost still more. Now, since it costs about as much to handle one kind of rock as another, it is very evident that the cost of handling narrow and non-continuous orebodies may be many times greater than the cost of mining orebodies large enough to afford room to work in. A sort of dead line is established by a thickness of approximately four feet. Orebodies thicker than four feet are only moderately cheaper to handle than those of about that thickness.

The attitude of an orebody has a great deal to do with the cost of extracting it. For instance, in the anthracite coal-fields, in Pennsylvania, and in various other coal-fields, the beds are thrown into a succession of folds with constantly varying slopes. The effect of this is double. First it renders more difficult the taking of the material from the working places to the haulage roads, and secondly it renders necessary a large amount of dead work in order to reach the various parts of the beds and also prevents regular systematic working. These two factors are sufficient to introduce a great increase of cost over that of mining a flat and unbroken seam.[1]

[1] The importance of this factor is not sufficiently emphasized in the text. In a flat deposit work may be conducted permanently on one level. The shaft, once sunk, is completed and requires no further attention; the pumping and hoisting equipment are not complicated by any necessity of adapting them to a changing base, *i.e.*, removing pumps from one level to another and getting more powerful and larger hoisting engines to provide for increasing depth. Still more important is the comparative absence of deadwork, of the constant extension of horizontal openings on new levels, of the awkwardness and effort required to hoist materials, timbers and men up vertical or inclined slopes, and of the work of building chutes or other appliances for

Homogeneity of Ore.—The homogeneity of the ore is a factor of great importance. This quality determines whether it is necessary to subject to metallurgical treatment the whole or only a part of an orebody. If only a part need to so treated we have a concentrating ore. The manner in which the valuable mineral lies in the enclosing rock determines how the concentrating must be done. In any case the process of concentration involves loss and expense, and the question of how far this loss and expense is justified depends on the cost and character of the subsequent metallurgical treatment.

The cost of the metallurgical treatment depends primarily on the proportion of ore that must be treated. This proportion varies at different mines from 2 to 100 per cent. Obviously, where only 2 per cent. must be treated the cost of treatment as applied to the whole orebody will be less than where all is treated. The inherent metallurgical problem is therefore only reached when the question of selection is settled.

Low Costs in Mining May Mean Greater Expense Elsewhere.—The above seems a sufficient explanation of the fact that it is necessary to a discussion of mining to include a consideration of the processes by which the ore is to be treated. It is not possible to run a mine intelligently without achieving whatever economy there may be in dressing the ore so that the further handling will be facilitated. Efforts to make "records" of low costs per ton have in many cases actually resulted in good mines being run at a loss. In this connection I can no better than repeat some remarks from an article published in the *Engineering and Mining Journal* some years ago on "Mining Costs at Cripple Creek."

"Let us take as a practical example a body of 10,000 tons of ore, running 1 oz. gold per ton. This ore can be shipped without sorting at a handsome profit, as follows:

Gross value of ore	$200,000
Cost of mining 10,000 tons at $3 per ton	$ 30,000
Freight and treatment, $8.25	82,500
Total cost	$112,500
Profit	$ 87,500

transferring ore or rock to a haulage line. The cost of mining a vertical or inclined deposit may be two or three times as great as it would be to mine the same deposit if it were flat. It appears that the least favorable inclination is one of from 15 to 25 degrees, such that the rock will not slide down, but yet the steepness prevents ordinary tramming.

Faulting of the beds or veins and the occurrence of barren patches introduce complications similar to those caused by folding, but very much more variable in their nature. The folding of the formation is invariably regional and is felt rather uniformly by all of the mines in a given district, while a series of faults may affect only one mine in a group and while that mine may have just as good ore and as much of it as its neighbors its costs will be higher.

"But suppose we reject half of this ore by sorting. By so doing we throw away 5,000 tons that will average \$2.50 per ton, or \$12,500. The cost of sorting, at 50 cents per ton, will be \$2,500 more. Then our shipment will be as follows:

5,000 tons, at \$37.50 per ton	\$187,500
Cost of mining and sorting, \$6.50 per ton	\$ 32,500
Freight and treatment, \$11.25	\$ 56,250
Total cost	\$ 88,750
Profit	\$ 98,750

"In other words, the gross receipts in this case have fallen \$12,500. The cost of mining per ton is more than twice as great; the cost for freight and treatment per ton is \$3 greater. The apparent showing by the superintendent is very bad; but nevertheless he has made for the company \$11,250 clear profit on the transaction.

"In the first case our total cost for mining, freight, and treatment is only \$11.25 per ton; in the second case it is \$17.75 per ton, but there is more money in the higher cost. This is an example that has been worked out in practice."

A false economy often results also from mining too much in a mere attempt to produce a greater output than the development of the mine really warrants. This invariably results in mining waste at a dead loss, but as this loss is on the same basis as the above, there seems no need to follow the discussion further.

Effect of Losses in Determining Costs.—Mining, milling, and smelting losses often foot up to a total that is simply alarming. Now since it is almost self-evident that crude methods involving high losses may be cheap as regards operating costs, there is always likely to be a question whether there is any economy in low costs obtained at the expense of undue waste, or whether, on the other hand, high efficiency of methods may not be at the expense of excessive cost. I think it has seldom been considered that there are such substantial losses in each department of the business. If we hear a discussion of mill losses in a given district it is to be noticed that the question of mine losses is apt to be ignored; if attention is called to mine losses there is apt to be silence on the subject of smelting losses. It seems desirable, therefore, to draw attention to some of the salient facts in regard to losses.

There never was a mine from which all the available ore was extracted. The ore is exposed to wastage from a variety of causes. If the orebody is large, soft, and homogeneous, as in the Lake Superior iron mines, ore is lost through absolute failure to mine it. Some is forgotten until the openings to it are caved and lost. Some ore is constantly being mixed with sand or rock and left because its grade has been lowered. Some is surrounded by the caving of the overburden into the mine openings in such a manner as to be irrecoverable. System, care, and expense

will do much to diminish these losses. It may happen that beyond a certain point the cost of perfecting the extraction may increase very rapidly, may indeed necessitate a different and more costly method of mining.

Since mines are worked for the profit and not for the gross value of their output it may be more economical to choose a cheap method in which the waste of ore may be great. For instance, suppose an ore worth $2 a ton can be mined with a 90 per cent. extraction for $1.25 a ton, but that by another method at a 75 per cent. extraction, it can be mined for 90 cents a ton. One hundred tons of ore in the ground would in the two cases yield the following results:

Ore worth $2 per ton

	Tons	Cost	Velue	Profit	
First case..........	90	$112.50	$180.00	$67.60	
Second case........	75	67.50	$150.00	82.50 =	$15 gain.

Ore worth $5 per ton

	Tons	Cost	Value	Profit	
First case..........	90	$112.50	$450.00	$337.50	
Second case........	75	67.50	375.00	307.50	$30 loss.

It is evident, therefore, that even in the most homogeneous materials the cost of mining is directly affected by the value of the product.

The proportion of the deposit that may be sacrificed to obtain lower costs increases as the margin of profit diminishes. When that margin becomes zero, obviously its value is zero and the whole deposit being unworkable is left in the ground.

Other Causes of Loss.—In flat deposits in hard rock it is nearly always necessary to leave some ore in pillars. Where the deposits are steeply inclined some ore is usually left in pillars unless the body is exceedingly small. In the case of very large bodies of low-grade ore, like the Alaska-Treadwell, large amounts are left in this manner, not only to insure the safety of the mine but also to insure cheapness of working. In every case where pillars are left there is a likelihood of portions being ultimately lost.

Where ores are sorted, *i.e.*, where they are not homogeneous, some good material is always rejected through ignorance or carelessness. Where filling is introduced into a stope there is invariably a certain amount of good ore that falls in with it and is lost. Where low-grade ores are sorted out and stowed underground because they cannot be shipped and treated except at a loss there is a great loss of metallic value, but since it cannot be said that such material is payable it cannot under present conditions be called a loss.

These mining losses are, I believe, seldom measured. More or less accurate guesses are made by the engineers on the ground, but the losses in mining are almost never seriously reported. In a general way we may place mining losses at from 5 to 30 per cent. of the developed ore.

Losses in Milling and Smelting.—Milling losses are in some localities painfully and accurately studied; in other places they are casually guessed at or ignored. It is usually fashionable to guess the extraction at 80 to 90 per cent. for concentrating and at about 95 per cent. for cyaniding or chlorinating. Sometimes, as a matter of fact, losses in concentration amount to 40 per cent. or even more. When the milling is not systematically and accurately checked the losses as a rule are much higher than the owners imagine. Little definite information is to be had.

Smelting losses are probably determined much more accurately than either mining or milling losses, but they are almost never mentioned in reports to stockholders. In this department of the business it is necessary to take more or less general statements of metallurgists.

The importance and economic bearing of the losses sustained in some representative districts are shown in an accompanying table. Much care must be exercised in the interpretation of these figures for economic purposes. The values thrown away are theoretical values. The practical limit of extraction invariably falls short of 100 per cent. The real purpose of the table is to show in current practice the debatable ground in which the curtailment of losses is confronted by a rising scale of costs.

PROPORTIONATE RECOVERY AND LOSSES IN 100 TONS OF ORE IN SOME IMPORTANT MINING DISTRICTS

	Pittsburg coal	Lake Superior iron	S. E. Missouri lead	S. W. Missouri zinc	Lake Superior Copper	Cripple Creek gold
Gross value in the ground	$110	$800	$460	$500	$280	$100
Gross value recovered by mining	88	$600 to 760	400	$375 to 475	246	$850 to $950
Gross value recovered by milling			$300 to $340	187 to 300	186	782 to 912
Gross value recovered by smelting		550 to 744	270 to 332	163 to 260	180	840 to 940
Gross aggregate losses	$22	$56 to $250	$128 to $190	$240 to $337	$100	$60 to $160
Per cent. recovered	80	70 to 93	58 to 72	33 to 52	64	78 to 94

The aggregate losses represent the maximum of additional operating expense theoretically justifiable by the extinguishment of losses.

It has been shown in the case of Cripple Creek ores how a mining cost may be too low, and it may be shown in the same way that milling and smelting costs may be too low. As a matter of fact they are very apt to be too low; rather more often too low than too high. Nevertheless it is perhaps well to point out that the economical cost is always a function of the value of the product. Of the various products of mines gold is the only one whose value is fixed. Where the product is variable in price the proportion of the losses is constantly changing, and the amount of expense warranted by the pursuit of such losses also varies.

Since the operation of a mine, mill, or smelter is usually a thing that does not lend itself to a ready adjustment, we find that refinements of methods designed to limit losses are fixed to those that will be economical at rather low prices. For instance, we find copper plants are planned to make savings that will be economical at 13-cent copper instead of at 25-cent copper; lead plants are planned for 4-cent lead and not for 6-cent lead, etc.

Waste in Exploitation.—At this point it may be pertinent to remark that questions of mere economy and profit may come into conflict with public policy. Much has been said about the necessity of conserving the forests of the United States. A forest when denuded is not beyond the possibility of ultimate replacement; an orebody or a coal seam, on the other hand, once destroyed is gone forever. It is very likely out of the sphere of the Government to interfere in the disposition of properties that have passed to private ownership, but it is quite feasible for the Government to take measures to prevent undue waste in the exploitation of the lands that it still retains; and it seems fully worth while for large private proprietors to consider the future as well as the present and to take measures to prevent some of the shameful wastes that are going on.

For instance, no one will deny that ultimately the world will need every ton of coal that can be had. Future generations will be very glad to mine coal from 2-ft. seams, many of which are now utterly destroyed by the working out of thicker seams not far below them. Similarly, it would seem worth while for land owners to bring pressure to bear in the working of metal deposits like those of southwestern Missouri where there is a waste of at least 50 per cent. of the zinc, and at Lake Superior where there is an enormous waste of low-grade iron ores which have been caved in and left behind during the extraction of richer portions. Wherever the introduction of these economies in material can be effected without financial loss, their introduction can do the operators no harm and will certainly be a benefit to the land owners and to the public at large.

Statement of Mining Costs.—A true statement of mining costs, therefore, should with due consideration of the above factors fall under the following headings:

(1) General expense of the company		1
(2) Mining	Exploration and development	2
	Stoping cost	3
	Stoping and sorting losses	4
	Amortization of mining plant	5
(3) Milling	Transportation to mill	6
	Operating costs	7
	Losses	8
	Amortization of milling plant	9
(4) Smelting, refining and marketing	Transportation to smelter	10
	Operating costs	11
	Losses	12
	Amortization of smelting plant	13

Unfortunately it is impossible to treat the subject so comprehensively owing to the absence of adequate reports. Most companies are igorant of both their costs and their losses; some know their costs but do not know their losses; very few know both. Some of the most scientifically managed concerns, like the American Smelters Securities Company, issue very few reports, although the management of this company does publish one report, that of the Esperanza Limited, which tells the whole story, but even in that model statement there is no specific reference to the amortization costs nor to mining and smelting losses.

Where a company does not own a mill or smelter it cannot, of course, state details for any amortization charges or operating costs or losses for those departments. Nevertheless, these things cannot be ignored either scientifically or commercially. Charges for them are fixed by contract. When a mine sells its ore to a smelter it pays commercially for amortization and operation of the smelter under treatment charges and for the losses by arbitrary deductions.

In the absence of such reports as will give the essentials the most feasible plan of treating the subject seems to be to divide the costs into three main headings: (1) Mining, including development; (2) milling, including transportation from mine; (3)smelting, refining, and marketing, including transportation from mill and to markets.

Generally the reports, or reliable information, are sufficient to give a fairly close approximation to the costs. It is seldom indeed that any statement can be found showing the charge to be made under each of these headings for amortization of plants, but there is usually some means of getting an idea of it. This can be done many times by simply ignoring credits to capital on construction accounts over a considerable period of years. This can be done on the logical principle that since the construction is all for the benefit of the operation of the mine it should all be absorbed in operating accounts. It will hardly be advisable to give in all cases the sources of information on which the cost estimates are based; but it is possibly worth while to assert that the figures are not far from the truth in spite of certain differences from published statements.

Management.—In discussing the factors that determine the cost of mining I have touched thus far only upon the tangible and definite ones of whose importance we can get a more or less logical measure; but the discussion would not be complete without some mention of the intangible and unmeasured but important factor of management. I wish to apply the term in its broadest sense and include in it the financing of an enterprise, the determination of its scope, the selection of its methods, and its administration.

To begin with, it is noticeable that enterprises in a given district have much in common and are apt to differ in methods from the enterprises of other districts. For instance, in Cripple Creek it is rare for a

mining company to treat its own ores, while in Butte most companies have done so; in the Lake Superior copper mines the underground work is done largely by contract with the miners, while in Arizona this is exceedingly rare, and so on. Each district has its own peculiar methods.

There is a probability that the methods of a given district are pretty nearly correct because they are inevitably the result of experiment, or evolution, and the fit have survived. It is logical to expect this. When a man comes into a district that is new to him and says that the industrial methods in use there are wrong, he does nothing less than declare that the thousands of people who have developed those methods are either ignorant or stupid or lacking in enterprise. Once in a thousand times he may be right; in 999 cases he doesn't know what he is talking about.

To illustrate how profoundly true this principle is even in the face of reasons to the contrary, I may be pardoned for relating an experience of my own: While traveling on the slopes of the Andes in Ecuador ten years ago I noticed that my traveling companion, a Spanish-American, did not wash or bathe, but carried in his vest pocket a small bottle with which he occasionally rubbed his nose. Whenever we came to a stream I would very likely take a bath. To this Rodriguez objected vigorously, saying, "If you want to live in this country without getting the fever, you must observe two rules, namely, sleep in a closed room, and don't bathe out of doors." I told him, and thought that the true laws of health demanded fresh air and cleanliness, and probably every Anglo-Saxon would have said the same thing. But, on returning to this country a few months later, I heard of the mosquito theory of malaria and saw a new light. Rodriguez was right. Observation had taught the natives empirically two ways of keeping off mosquitoes and fairly effective ways. They could not give the reasons but they got results. It is quite true that a mosquito net is just as good as a coat of dirt to ward off the fever-bearing insect, and that by means of it one may also enjoy the luxury of fresh air; but the point is the *mosquito must be kept out.* The person who does not realize this is running a risk of death from sheer ignorance. The same thing may be said of superficial criticism of customs in general and of mining customs in particular. There is very apt to be a "joker" in the game of the rash innovator and he may find himself and his new methods up against a hand of five aces.

I feel, therefore, that, as a general rule, it is unfair and stupid to measure the methods of one district by the standards of another, but this does not mean that the methods in use are always the best. Among operators in the same district, where all are equally conversant with the governing factors of the situation, we will invariably find some who get better results than others. We will find, running side by side mines that show great and apparently inexplicable differences in cost. We will find in any district examples of mines that have failed under one

management and succeeded under another. While the effect of management is well understood by every one, it does not lend itself to expression in figures; nevertheless there are some things that may be said of it of a nature pertinent to this discussion.

On thing has been noted as a rule; viz., rich mines cost more to run than low-grade mines. It is generally conceded that this is to be explained by the liberality of the carefree. There is something more than this. Suppose two deposits are found 20 miles apart, one of ore worth \$5 a ton, and the second worth \$2 a ton. The first is opened up by the first method that occurs to the owners, the ore is shipped and it is discovered that is costs \$3 a ton to mine it. The owners congratulate themselves on their 40 per cent. profits. Their business is established; they are making lots of money; to make changes and improvements is laborious, expensive, may involve delay in marketing the product and may not turn out well after all. Why not leave well enough alone?

The second body of only \$2 ore, after being opened up, is left alone for a while. It is considered too low-grade to pay. But some enterprising person at last comes along who thinks it may be worked. He chooses for a superintendent, not the first man he meets, last of all some friend or relative, but some one he thinks able to get results. All possible methods are studied in order to choose the cheapest. All possible precautions are used to avoid unnecessary expenditures on plant. Every employee is impressed with the necessity of efficiency. After the enterprise is finally going it proves that the ore is being mined at \$1.20 per ton and the triumphant owner of the \$2 ore also secures 40 per cent. profit on his product.

Logical Reason for Rich Mines Costing More.—There may be no physical reason for this difference in cost; there may be no intentional liberality on the part of the owners of the richer property. Nevertheless, there is a logical ground for a difference in the selection imposed by necessity. In the rich mine there is no necessary selecton; *ergo* there is no selection. We may, therefore, count on a certain increment, sometimes very large, sometimes very small, of additional expense in mining rich ores as compared with poorer ores.

Necessity may work vast economies in the same mines. The Champion iron mine at Beacon, Mich., was producing ore in 1892 at \$2.50 a ton. It had then been running 25 years and was reputed to be a very well managed mine. In 1899, the mine was deeper, the orebodies smaller, wages the same, the plant the same, the management the same, but the ore only cost \$1.25 per ton. Necessity had worked this change through the panic of 1893. Similar changes were wrought in other mines.

Hoover's Theorem.—The economic ratio of treatment capacity of ore reserves is a question that has been brought up by H. C. Hoover and vigorously discussed by many prominent engineers. Ross E. Browne

("Working Costs on the Witwatersrand") has recently brought additional evidence to bear out the correctness of Mr. Hoover's conclusions that economically mines should be worked out with great rapidity and that additional plant should be provided for the extraction of discovered ores within periods of from three to six years. There seems to be no doubt of the mathematical correctness of this conclusion, but it seems to apply logically only to gold mines where there is no practical limit to the sale of the output. In the mining of products other than gold it seems that a limitation is put upon the output by the market. In the case of Lake Superior iron ores, for example, there are fifteen hundred million tons in sight. To work these all out and convert them into pig iron in six years is not only a physical impossibility, but would be economically absurd. It is not at all absurd, however, for an isolated operator among many to apply this principle to his own profit. It may be that the application of this very principle has resulted in the formation of gigantic trusts. It seems probable that the growth of the Carnegie Steel Company in competition with its neighbors may have been largely due to the application of this idea to steel manufacturing; but in course of being fully worked out, the result was the formation of the United States Steel Corporation which now controls 75 per cent. of the iron ores of Lake Superior and from mere extent of growth has landed in a position where the application of Mr. Hoover's principle is no longer possible.[1]

Economy and Speed.—It is to be remarked in this connection that a wide-awake manager may see his way clear to overlook questions both of a high percentage of extraction and of cheap work to reap the benefits incident to speed. Take, for example, a body of soft iron ore of limited cross-section pitching rather steeply into the earth. The requirements of thorough extraction and cheap working would very likely be satisfied by the use of the slicing system of mining, but in such a case the volume of product would be limited because the area on which slicing can be conducted is practicaly limited to a single horizontal section of the orebody. This limitation of the product during years of high prices might be a very serious handicap and it would probably be wise to adopt a different system, perhaps less effective and more costly, but which would allow the working of a number of levels at once and the turning out of a large output at an advantageous time.

The management of large properties may come into conflict with public economy in the following way: Large sums of money are locked up in the purchase of great tracts of mineral lands, far in excess of the requirements of the immediate future. The sums thus invested are usually raised by bond issues and the interest on these, together with taxes, amount annually to large sums which the public must pay. These

[1] These were the figures in 1908. Since then changes and developments have altered the proportions somewhat.

charges are inevitable, and are quite independent of any desire on the part of such holders to raise prices through the opportunities afforded by the existence of partial monopolies. Conspicuous examples of this state of affairs are afforded by the United States Steel Corporation, especially since it has absorbed the Tennessee Coal, Iron, and Railroad Company, and by the Philadelphia & Reading Coal and Iron Company. Both of these great corporations have mineral lands sufficient to guarantee their product far into the future, but they represent investments on which charges of many million dollars a year must be paid without any immediate return.

CHAPTER V

PARTIAL AND COMPLETE COSTS

TERMINOLOGY AND METHODS OF ANALYSIS—PARTIAL AND COMPLETE COSTS—OPERATING, MAINTENANCE, DEPRECIATION, AND AMORTIZATION—DIVIDEND COSTS AND SELLING COSTS—EXAMPLES OF DEPRECIATION—ANALYSIS OF COST STATEMENTS—AMORTIZATION TABLES—TABLE OF PLANT COST PER ANNUAL TON AND LIFE OF MINES—INVESTORS' PRECAUTIONS.

I KNOW from experience that many operating men, though deep in details, are acquainted only with partial costs. Their point of view does not reach the *tout ensemble*. For instance, a man may be in charge of a mine and called manager or superintendent. His business ends when the ore is delivered into cars to be shipped to the mill. Up to that point he thinks he is familiar with the costs. Probably he is not, though he may be. It is more likely that he knows little or nothing about the capital invested in the mine and the average annual value of it. He is probably full of information about the current operating costs of his one department—the mine. He does not know what is involved in transportation to the mill, in milling, in smelting, in general expense. His knowledge of the business as a whole is very limited. In talking with other mining men he may be elated or depressed at learning that his costs are lower or higher than theirs, but he may find out later that he has reasoned from false premises. He is really talking about a segment of the business to men who are also talking about segments of the business, and the segments may be, and are very likely to be, different in each case.

Now such a man is very apt to graduate into a mining engineer and to examine mines and report on them without once giving consideration to the limitations he is under. He repairs by experience some of his misapprehensions, but his conception of the business is very likely to remain only a partial conception; at the best he is clear about only a part and hazy about the rest.

The costs reported to stockholders and investors are very apt to be only partial costs. They are almost never so expressed as to give one a true understanding of the business. This may not be intentional; merely a narrow view of the financial realities. In the following chapters I shall review the statements of many mining companies and it will be seen that I have reconstructed nearly all of them, putting my own interpretation upon their figures and in many cases rejecting their figures as inadequate and substituting others. I would not be rash enough to do such things without reason. It is in every case merely drawing an

irresistible conclusion, such conclusions as no two men would argue about so long as they had the same point of view. I propose here to describe my method and point of view in cost analysis; but first I shall define certain expressions that are in common use in this discussion.

There is a certain confusion in the use of the terms, *operating, maintenance, depreciation,* and *amortization.* In this book I intend to have a perfectly clear meaning for three of these terms. *Maintenance* is a term to which I attach little importance. It is simply the cost of keeping things in good order and is an undeniable operating item. I shall assume under all circumstances that maintenance is inc uded under the head of operating.

Operating, or current operating, charges are those that relate to the obtaining of product. It includes all the labor, salaries, and supplies used on the actual yield of a mine for a limited period, but excludes all charges that may be a preparation for a yield to be obtained later. Note that I say "for a limited period;" for I make it a cardinal and self-evident axiom that whenever we extend our point of view to the whole life of a mine or property, we immediately abolish the difference between operating and capital costs. Then *all* expenses are operating expenses.

The capital charges of *depreciation* and *amortization* are only suspense accounts intended to exhibit the difference between operating for a short period and operating for the whole period. Now unless we are holding a post-mortem examination on a dead mine we never know just what the difference is. These items then are estimates, and I feel it necessary, in order that one may understand my cost analyses, to explain carefully how I make these estimates.

Frequent reference will be found in coming chapters to *dividend costs* and to *selling costs.* By selling cost I mean the real or complete cost, the cost at which the product must be sold to justify the enterprise. It includes all capital employed, with interest for the whole period of operating. Obviously, if these total expenditures amount to say $10,-000,000 and the total return is only $9,500,000, the enterprise is not a successful one. But suppose that of the ten millions spent, the sum of three millions is represented by two millions spent on initial plant and one million for interest on that sum at 5 per cent. for 10 years during which there were no dividends. These three million dollars are not operating charges, at least they are not the current daily operating charges that the mine manager knows about. His operating charges are only $7,000,000 while the proceeds are $9,500,000. Here we have $2,500,000 to be paid in dividends. Here our *selling cost* is $10,000,000. The enterprise is really a failure unless our returns equal that amount. But the dividend cost is only $7,000,000. This sort of a difference is practically universal in mining cost statements. I never knew of one in which the real selling cost was calculated.

As a general rule the cost of production is understated much more than it would be in this case if it were given at 7 instead of 10; because 7, the dividend cost, is in itself a composite figure. It consists of two elements: (*a*) those costs that plainly belong to merely getting out the product, and (*b*) some other costs that seem to be creating something permanent, but really are not. These things are apt to be euphemized into "capital charges." In the hypothetical case 7, being the dividend cost, is very apt to be made up of the figures 5 and 2; the first being "working charges" and the second being "construction." This construction seems to be permanent; it is "doing great things for the property," "working wonders." In fact it is absolutely essential; but it must be paid for before dividends appear, and therefore is included in the dividend cost: but our euphemistic report gives the working cost, the cost of production, at 5.

Remembering that we found at the very beginning that the real cost was 10, we must explain that the difference is made up of *amortization* and *depreciation.* Amortization accounts for the difference between 10 and 7, depreciation accounts for the further difference between 7 and 5. The omission of these sums may not, possibly, be of any injury to any one; but it certainly results in an outrageous underestimate of costs.

By *depreciation,* then, I mean current construction costs; improvements. Until a mine is dead and ready to be buried in a watery grave there are always expenses of this kind. Depreciation means literally the process of losing value: practically it means the exact opposite; it means expenses undertaken to counteract loss of value. It may be asked, why is this not maintenance? It *is* maintenance. It only *seems* not to be maintenance because the items that compose these charges have the appearance of being new plant, not merely replacements of old plant. I shall give some examples.

Let us suppose a mine to be started on a very large tract of land (to avoid all complications except natural ones, let us get rid of our neighbors), with a vein running north and south and dipping vertically. Two shafts are started, a mill erected and the property put in operation. At the depth of 500 ft. the south shaft runs out of the ore; but the north shaft is in good ore at 700 ft. Every level goes farther in that direction than the one above it. A new shaft must be sunk, No. 3, further north. It must be sunk 1500 ft. at a cost of $150,000 before it produces anything.

Such an expenditure is often set down as "capital," but this would be frequently misleading. The construction and equipment of No. 3 shaft is pure depreciation—an expenditure that should be written off to operating as fast as it is made. No. 3 does nothing but take the place of the south shaft.

Again, the original north shaft has reached the bottom of the ore. "We have again been disappointed. It was unfortunate that we equipped No. 3 as we did," I might quote from an imaginary, but very frequent report, "because certain unforeseen conditions have arisen that make it evident that a different plant would have served our purpose better. It is found now that the ore shoot has a pitch averaging 54° to the north along the plane of the vein. Evidently a shaft inclined to the northward at that angle would follow the ore. A single shaft like that would accomplish our purpose as well as a number of vertical ones, or a series of long drifts from a single vertical one. Moreover, we find that at the 1500-ft. level of No. 3 shaft the vein, instead of standing vertical as it has above, is now dipping to the west at an angle of only 45°. After mature consideration it has been decided that our best course will be to put a curve in No. 3 shaft and change it into an incline below the 1500-ft. level, following the oreshoot in a northwesterly direction. This will necessitate changing our equipment. Our flat rope hoist, designed for handling cages in a vertical shaft, must be replaced by a round rope engine with a drum. We must install skips, for which our engineers assure us it will be best to cut undergrouud loading pockets." It is useless to proceed further. It is the same problem that caused the sinking of No. 3 shaft. The solution, however, appears new.

One might cite "capital charges," "construction" or whatever it is called, in hundreds of cases like the above. The same thing appears in all kinds of disguises. There are always expenditures going on that appear to be for permanent improvements, really are for permanent improvements, but which are really nothing but expenses required to keep the property from depreciating; in other words, to enable it to be a good plant and not get antiquated, or no longer adequate to changed requirements. Money is even spent uselessly, often merely for fashion; for fashion is so far from being confined to women's finery that it reaches the methods and appliances in the depths of mines.

Sometimes construction that amounts to nothing but depreciation is combined with construction that does make a real addition to capacity and earning power and is truly capital. It is necessary, therefore, to explain that in the analyses of cost in the following chapters I have not followed any exact rule. The analysis is founded on the circumstances exhibited by the reports. These, however, fall into two general groups: rich mines that have built up their plants entirely out of profits or in which at least there has been a continuous growth so that the original capital is only an insignificant fraction of the total investment; and low-grade mines not rich enough to start themselves and not profitable enough to make the original investment soon disappear. In the first case I make no attempt at calculating amortization, but adopt the much simpler method of writing off all expenditures, over as long a period as I can

get figures for, to the cost of the production. In the second case I charge all expenditures of every kind to capital up to the time when the mine is producing. After it is producing I charge to capital those expenditures made to increase the capacity until the mine has reached what appears to be an average production. Then this total is written off, with interest, over a period that seems reasonable, by charging up each year a sum calculated to retire the investment within the required time.

This charge is the *amortization* of capital.

Ordinarily I put the period of initial capital expenditure as far back as possible and, unless the increase of capacity is very considerable, I charge off the yearly new construction to operating and call it *depreciation.* In most cases those who are interested will see from the cost analyses themselves the method adopted.

A word further about amortization. When the sum to be written off is determined it is necessary to fix two further elements; the rate of interest to be charged and the period in which the principal must be extinguished. The first I have taken in all cases at 5 per cent. The second is the great field where judgment and experience come into play; wherein the mining business exhibits its peculiarities and where it is different from any other form of commercial enterprise. We must discuss it fully, but first let us show the methods by which amortization may be calculated. One way is shown by the following table in which a sum of money is returned to the investor in equal installments, which which are supposed to be part interest and part principal. The part that represents the return of principal for each year is deducted from

AMORTIZATION TABLE.— 5 PER CENT.

Showing number of years in which $1,000 is cancelled at 5 per cent. annual interest and 5 per cent. amortization, or $100 annual installment.

Years	Amortized	Interest	Balance due
1	50.00	50.00	950.00
2	52.50	47.50	897.50
3	55.12	44.88	842.38
4	57.88	42.12	784.50
5	60.77	39.23	723.73
6	63.81	36.19	659.92
7	67.00	33.00	592.92
8	70.35	29.65	522.57
9	73.87	26.13	448.70
10	77.56	22.44	371.14
11	81.44	18.56	289.70
12	85.51	14.49	204.19
13	89.79	10.21	114.40
14	94.28	5.72	20.12
15	98.99	1.01	0.00

the original sum, and for the next year interest is calculated only on the diminished principal; but, since the yearly installments are equal, as the yearly interest requirements diminish the part applying to the return of principal will increase so that the extinction of capital becomes progressively more and more rapid.

Another method of extinguishing capital by annual installments is by creating a sinking fund which will increase by investment. The sum of the investment of annual installments with accrued interest is supposed to equal the capital at the end of the required period. The following tables designed to exhibit this method are taken from Hoover's Principles of Mining.

PRESENT VALUE OF AN ANNUAL DIVIDEND OVER — YEARS AT — PER CENT. AND REPLACING CAPITAL BY REINVESTMENT OF AN ANNUAL SUM AT 4 PER CENT.

Years	5 per cent.	6 per cent.	7 per cent.	8 per cent.	9 per cent.	10 per cent.
1	0.95	0.94	0.93	0.92	0.92	0.91
2	1.85	1.82	1.78	1.75	1.72	1.69
3	2.70	2.63	2.56	2.50	2.44	2.38
4	3.50	3.38	3.27	3.17	3.07	2.98
5	4.26	4.09	3.93	3.78	3.64	3.51
6	4.98	4.74	4.53	4.33	4.15	3.99
7	5.66	5.36	5.09	4.84	4.62	4.41
8	6.31	5.93	5.60	5.30	5.04	4.79
9	6.92	6.47	6.08	5.73	5.42	5.14
10	7.50	6.98	6.52	6.12	5.77	5.45
11	8.05	7.45	6.94	6.49	6.09	5.74
12	8.58	7.90	7.32	6.82	6.39	6.00
13	9.08	8.32	7.68	7.13	6.66	6.24
14	9.55	8.72	8.02	7.42	6.91	6.46
15	10.00	9.09	8.34	7.79	7.14	6.67
16	10.43	9.45	8.63	7.95	7.36	6.86
17	10.85	9.78	8.91	8.18	7.56	7.03
18	11.24	10.10	9.17	8.40	7.75	7.19
19	11.61	10.40	9.42	8.61	7.93	7.34
20	11.96	10.68	9.65	8.80	8.09	7.49
21	12.30	10.95	9.87	8.99	8.24	7.62
22	12.62	11.21	10.08	9.16	8.39	7.74
23	12.93	11.45	10.28	9.32	8.52	7.85
24	13.23	11.68	10.46	9.47	8.65	7.96
25	13.51	11.90	10.64	9.61	8.77	8.06
26	13.78	12.11	10.80	9.75	8.88	8.16
27	14.04	12.31	10.96	9.88	8.99	8.25
28	14.28	12.50	11.11	10.00	9.09	8.33
29	14.52	12.68	11.25	10.11	9.18	8.41
30	14.74	12.85	11.38	10.22	9.27	8.49

PRESENT VALUE OF AN ANNUAL DIVIDEND OVER — YEARS AT — PER CENT. AND REPLACING CAPITAL BY REINVESTMENT OF AN ANNUAL SUM AT 4 PER CENT. *Continued*

Years	5 per cent.	6 per cent.	7 per cent.	8 per cent.	9 per cent.	10 per cent.
31	14.96	13.01	11.51	10.32	9.36	8.56
32	15.16	13.17	11.63	10.42	9.44	8.62
33	15.36	13.31	11.75	10.51	9.51	8.69
34	15.55	13.46	11.86	10.60	9.59	8.75
35	15.73	13.59	11.96	10.67	9.65	8.80
36	15.90	13.72	12.06	10.76	9.72	8.86
37	16.07	13.84	12.16	10.84	9.78	8.91
38	16.22	13.96	12.25	10.91	9.84	8.96
39	16.38	14.07	12.34	10.98	9.89	9.00
40	16.52	14.18	12.42	11.05	9.95	9.05

Annual rate of dividend	Number of years of life required to yield — per cent. interest, and in addition to furnish annual installments which, if re-invested at 4 per cent. will return the original investment at the end of the period.					
Per cent.	5 per cent.	6 per cent.	7 per cent.	8 per cent.	9 per cent.	10 per cent.
6	41.0					
7	28.0	41.0				
8	21.6	28.0	41.0			
9	17.7	21.6	28.0	41.0		
10	15.0	17.7	21.6	28.0	41.0	
11	13.0	15.0	17.7	21.6	28.0	41.0
12	11.5	13.0	15.0	17.7	21.6	28.0
13	10.3	11.5	13.0	15.0	17.7	21.6
14	9.4	10.3	11.5	13.0	15.0	17.7
15	8.6	9.4	10.3	11.5	13.0	15.0
16	7.9	8.6	9.4	10.3	11.5	13.0
17	7.3	7.9	8.6	9.4	10.3	11.5
18	6.8	7.3	7.9	8.6	9.4	10.3
19	6.4	6.8	7.3	7.9	8.6	9.4
20	6.0	6.4	6.8	7.3	7.9	8.6
21	5.7	6.0	6.4	6.8	7.3	7.9
22	5.4	5.7	6.0	6.4	6.8	7.3
23	5.1	5.4	5.7	6.0	6.4	6.8
24	4.9	5.1	5.4	5.7	6.0	6.4
25	4.7	4.9	5.1	5.4	5.7	6.0
26	4.5	4.7	4.9	5.1	5.4	5.7
27	4.3	4.5	4.7	4.9	5.1	5.4
28	4.1	4.3	4.5	4.7	4.9	5.1
29	3.9	4.1	4.3	4.5	4.7	4.9
30	3.8	3.9	4.1	4.3	4.5	4.7

Let us now return to the problem of fixing the time for the amortization of invested capital. As remarked above, this is easy in the case of a worked-out mine. To do it accurately in the case of a living and prosperous mine is, frankly, impossible. But as this is a vital question for every investor it is absolutely necessary to give an answer, be it correct or not. For, whether the investor realizes it or not, he is always staking his capital on the probability of having it returned within a certain time. In other words, he is gambling on the life of the mine. If a man invests money in a mining stock which yields only 5 per cent. on the price he pays for it, and if at the same time he can get 5 per cent. on a well-secured bond, he must calculate that the mine is as permanent as the bond. If he gets a dividend of 10 per cent. and calculates that 5 per cent. is a sufficient interest on his money, it follows that he is counting on a life of at least fifteen years for the mine.

It happens that the probable life of mines varies between wide limits. In the case of coal, building stone, cement, iron ore (and in sporadic cases among precious metal ores), it has been proved possible to find enough ore in a few years to assure the life of the enterprise twenty or more years in advance. Of course the period of activity in sight is the minimum amortization period; the longer the period the more stable the investment, because the longer the life the greater the probability of equalizing vicissitudes. But in general the mines that can see ahead twenty years or more are rare. Many profitable ones have not a single year's ore in sight and yet the probabilities may be in favor of a considerable life. The only means by which one may form an opinion of the probabilities are acquaintance with the history of mines and ore deposits, and acquaintance with the state of development of the property, the rate of extraction, the ore in sight, and the soundness of the management. The cardinal point for the reader's attention is the varying life estimate for various types of mines, and the highly variable rate of amortization that this estimate imposes.

How These Figures Interest the Investor.—The question is often asked, What bearing do these theoretical or half-forgotten questions about capital originally invested, and its theoretical retirement, have for the investor who buys or sells stocks in mining properties at valuations that have not the slightest reference to the original investment or how it is disposed of? To this various answers may be given. I have already pointed out, but may as well repeat (it cannot be repeated too often), that exactly the same considerations apply to the extinguishment of the price paid for a share of stock, which is the form in which investment is made by the average man, as apply to the capital used to build a mill. It is no argument to say that mining shares are mainly used as counters in a game. That it is true at all is due only to the fact that a portion of the public is imposed upon by false analogies; they are often induced to

buy highly speculative mining stocks on the same income basis as they buy the soundest securities. The very mining shares that I have called "highly speculative" might in many instances at a sane valuation be just as "sound" as the soundest.

A sound business must be a paying business; one that is good for both interest and principal. The great fault with the mining business from the point of view of the moderate investor is that it is very easy for the sake of a fair amount of interest to lose the principal. There is no need of this. By studying out the vital question of the life of a mine with its concurrent rate of amortization, and by steadily refusing to believe that the current construction is "capital," one may eliminate overvalued properties pretty rapidly. It is a good rule not to buy stocks in concerns that are too wise to issue full reports. If there is any business in the world where a full knowledge of certain elemental facts is necessary for a safe and sane investment it is surely mining.

Furthermore, at the last analysis the price of a commodity must be governed by its cost. It is highly important, therefore, to know when prices are excessive and therefore unstable. It is one of the objects of this book to show what the cost of production on a grand scale in various important products of mines really is. In such computations the capital charges are a vital factor and I have thought it desirable to explain as fully as possible my conception of a proper treatment of them in order that the reader may be able to judge for himself the justness of my conclusions.

One rather curious fact should be borne in mind *i.e.*, that depreciation will vary not according to the original cost of a plant but according to the prevailing level of prices. The analogy of an automobile is perhaps clearer to the average person than that of a mine, but I am satisfied that it is as true for the latter as for the former Suppose a man bought an automobile in 1917 for $2,000. If the price level were the same he might have sold this car and obtained a new one for $1000 additional. That would have been his depreciation. But in 1919 a car of the same class might sell for $3000—and his first car might have value in proportion, say $1500. But his depreciation would be $1500.

Thus in many cases sums set aside for depreciation in pre-war times must now be insufficient.

CHAPTER VI

COAL

IMPORTANCE OF COAL—REMARKS ON ITS ORIGIN—CYCLES OF GEOLOGIC HISTORY—THE PALEOZOIC COAL FIELDS—MESOZOIC—TERTIARY—STATISTICS OF COAL PRODUCTION.

Modern civilization is propelled by the annual combustion of upward of 1,500,000,000 short tons of coal. This vast use of power other than human or animal muscle is the basic fact in the mightiest revolution in industry, in art, and in habits that the human race ever experienced. Every time we press a button to turn on an electric light, every time we enter an elevator or a street car, we participate not only in a human revolution, but in a great geologic fact; for the mining and destruction of coal removes some of the important strata of the earth's crust.

Coal mining is the basis and dependence of other kinds of mining just as it is of other industries. And farther, since coal mining is one of the simplest and commonest of mining operations, it serves as a standard by which the complexity and cost of other kinds of mining may be appraised.

If coal were not so abundant and widespread its use could not, of course, be so extensive and fundamental. The fact of its wide distribution is the most powerful element in the conduct of the business. If coal were not cheap it could not be so extensively used; it would not, therefore, be so valuable. But because it is cheap it is often wasted; it is cheap because it can be offered in the market by innumerable competitors, whose aim is not the wise use of coal, but ready money profit from it. Hence this most valuable of mineral resources has been in considerable measure crudely and greedily exploited.

The subject of the origin, history and distribution of this substance is simple enough to be understood easily by any one willing to give it attention; but at the same time it involves facts about the changes that have taken place, and are still taking place, on the earth's crust that are hard to grasp. Coal is being formed at the present day in immense quantities over immense areas. The present age is therefore a coal forming age, but whether conditions are favorable for burying it under accumulations of sediment so that the coal now being formed may be preserved indefinitely in the earth's crust, and whether the formation of coal is more general in this age then in past geological ages, or less so, are questions not so easily answered. Coal is nothing but buried peat;

coal formations are nothing more than a series of swampy land surfaces that were finally buried in a variety of ways under sediments.

People living in certain areas of the Anglo Saxon world, for instance, those of the southwestern half of the United States, of the whole of Australia and South Africa may never have seen a peat-bog or have any clear idea of what it is like. To these it may be a matter of surprise to learn that the natural surface of the earth north of a line drawn across North America from Vancouver Island to New York City, and across Europe and Asia from Paris to Moscow to Vladivostok, is occupied to a considerable percentage of its area by peat-bogs. How large the percentage is I do not know: to find out would be a question of mapping some 8 or 9 million square miles of land in a solid block occupying the sub-artic and north temperate zones of the northern hemisphere. In all this vast space, wherever the climate is damp enough or wherever the low lands are partially flooded, mosses and semi-aquatic trees like cedar, tamarack and alder spread over the surface, holding and absorbing water like a sponge. The trees and plants live and die partially immersed in water. When they fall they are in large part covered with water which preserves them indefinitely from decay. A woody, or at least a vegetable, mass accumulates for ages until it finally forms a muck of almost indefinite depth, always completely saturated with water under the spongy covering of moss. The moss indeed seems like a carpet spread over the surface of a lake; the traveler sinks in it to his knees, and while he sees before him the prospect of a wide plain or meadow he finds its surface trembling under his footsteps for yards around. If he has the bad luck to step into a water hole, or break through the mossy carpet, he instantly mires in the vegetable coze which may be a hundred feet deep. Such are the "tundras" of Siberia and Alaska, the "muskegs" of Canada, the "tamarack swamps" of Michigan, the bogs of Massachusetts and of Ireland and the marshes of Germany and Russia. I am sure that the area of these swamps is far greater than that of all the coal fields of the world put together. The vegetable ooze and the mat of preserved wood is peat. It is incipient coal. It constitutes in itself an unspeakably great potential fuel supply, at present only casually used because it cannot compete with the more convenient and desirable fuels that may be cut from the forest or dug out of the rocks.

These northern marshes are not the only places where peat accumulates. The cypress swamps of Arkansas and Louisiana, the dismal swamp of Virginia, the mangrove swamps of tropical tide flats are also receptacles for such vegetable ooze; but in general the south temperate and tropical zones are not very favorable for them. The hot sun quickly dries up a swamp unless it is replenished by a constant supply of water. Even an occasional drought will expose the vegetable mass to rapid destruction by oxidation or rotting; in a dry climate therefore, or in one

in which the rainy seasons alternate with prolonged droughts the process is impossible except under very unusual circumstances. That is why so many people may live and die without knowing what peat is, although it is really so abundant.

The mere growth of peat on the surface does not lead to the formation of coal. To complete the process it is necessary to bury the peat under sediments. The conditions that favor such burying are not by any means so common as those which permit of the accumulation on the surface. Undoubtedly most of the peat that forms is eventually destroyed again without ever being buried. A change of climate, or of drainage, easily puts it in the way of destruction.

The manner in which peat swamps may be effectively buried is well worth a moment's consideration. It is really a matter of common geography. Every school boy knows about the dykes of Holland and the levees of New Orleans; that these dykes are to protect large areas from overflow either by the tide or by the river floods or by both. Both tracts are in the deltas of large rivers—the Rhine and the Mississippi. When a river builds a delta into the margin of the ocean it raises a flat pile of mud higher and higher and the river itself debouches right on top of the pile and usually sends its waters trickling in smaller or larger streams down the sides of it in all directions. The banks of the main river and each branch are invariably higher than the country between the branches, at least they become so sooner or later. Eventually a stream will break through one of these banks and start a new channel in the hollow between old channels and eventually fill it up with silt higher than the old channels which in their turn become low ground. Suppose such hollows were filled with peat swamps; these swamps would sooner or later be covered by the river muds and the peat would become a coal bed. The Rhine delta is actually in a peat forming climate today and if it were not for the interference of civilization nearly the whole of Holland and a good part of Belgium and Friesland would be a coal forming region on no mean scale. All that would be necessary would be the continuance of the present climate and a maintenance of the present sea level; or, better still, a slow substance of the delta at approximately the rate at which the river can fill it up. The peat swamps might grow deeper indefinitely always keeping their surface up to the level, or slightly above the level, of the river channels, thus helping to maintain these channels for long periods. In this manner the rivers would slowly build their beds and banks higher and higher, and build out deltas further and further. The waves and shore currents would spread the mud in bars and beaches along the shores of the delta and enable the beaches to creep further out into the sea. As they crept out the peat bogs would follow them. Thus the whole area of the delta between the river channels and the sea beaches would be filled with enormous accumulations of peat interrupted, of course, by

occasional patches where overflows would pour in mud, by other patches where the water would become too deep for the swamp plants and thus make lakes, or by sand dunes blown up from the beaches. If the subsidence of the delta should become too rapid for the river to maintain it the sea would finally break through the beaches and begin flooding the swamps with salt water, killing the growth and immediately commence to cover the peat with beach sands and sediments. The shallow bottoms of the bays would be occupied by marine animals and plants: if the water were not muddied by a constant supply of fresh silt, a limestone might be deposited instead of mud. Still further a portion of the peat bogs might be rapidly covered by a march of sand dunes blown from the beaches.

Thus in the case of a large river delta in a damp, cool climate we can see how there might be very deep and very extensive deposits of peat and how these deposits would, in the course of time, under stable conditions be covered either by river mud, marine sediments or by wind-blown sand. It is also easy to see how a whole delta might be covered over by an acceleration of the subsidence, but when the subsidence ceased, or slowed up, a new delta would form right on top of the old one and as it grew out would cover up the old one to the new level of the sea, or of the new delta. New peat swamps would form on the new surface, which, by the way, would also extend further up the river valley and back over the lower slopes near the shore. Thus the process would go on until some radical change in the earth's crust would put an end to the formation of the delta, or change the climate so that peat swamps would no longer grow.

If Louisiana had the climate of Michigan we should see all these operations going on in this country on a huge scale. From Cairo, Illinois, to the Gulf and for vast stretches along the Gulf in Texas, Louisiana, Mississippi, Alabama and Florida there would be interminable peat deposits, all in process of gradual burying in the ways I have indicated. So far as I can see such deposits might easily be on a scale equal to anything known in the great coal beds of the world. For instance the Pittsburgh coal seam is believed to have been continuous over an area of 10,000 square miles. It is reasonable to expect that with no change whatever in conditions other than to substitute the climate of the Great Lakes a continuous peat swamp would form on the Mississippi Delta over even a greater area. The total area of lowlands in which swamp formation would be continuous and active must be more than 100,000 square miles. If this climate and these conditions were to continue indefinitely and if the weighting of the delta caused a slow subsidence the coal forming process would eventually spread over an immense area. A subsidence of 500 feet, an extremely moderate earth movement, geologically speaking, if accomplished slowly would cause the active delta and the peat forming area to march progressively up the valleys

beyond Kansas City, Chicago and Pittsburgh, leaving behind in the lower basin innumerable deposits of peat at different levels covered by a deep and ever deepening mass of sediments. Over the site of New Orleans limestone beds would now be forming and beneath them great coal measures, and no doubt oil and gas rocks also, would be securely locked. Such a development would be the counterpart of the great coal formation of the Carboniferous period, not, of course, on the same places but on an equivalent scale.

This, of course, is only a rule sketch of the major features of a coal forming period; there are innumerable variations of details of all kinds; but in general one may see in any coal mine an actual record of just such happenings. I have said that any observer who gives the matter attention can readily grasp the general features of this process; but there ought perhaps to be added one qualification, or explanation. The process of giving the matter attention is largely that of dissociating one's imagination from the limitations of human experience. It is difficult to picture the life scale of the earth instead of the life scale of a man. A generation seems a pretty full cycle and it is hard to get fully away from that conception of time; but to think effectively of geological processes one must banish that limitation completely. The span of human life or even the whole period of recorded history is such an insignificant fraction of time that the geological processes have made only trivial changes in geography during the whole of it. A coal forming epoch such as I have attempted to picture must be measured in millions of years rather than in thousands and yet it constitutes only a modest portion of geological history. In North America we are fortunate enough to have the coal left, and remarkably well preserved too, by three such general coal forming periods all on a truly collossal scale, besides several others of minor importance. The publications of the U. S. Geological Survey and of many of the State surveys are full of information about all this, a bulk of literature indeed too great for digestion, but for a general view one may read two volumes, Bulletin No. 38 of the U. S. Bureau of Mines by White and Thiessen, and Professional Paper 100 A, of the U. S. Geological Survey by Marius R. Campbell, on the Coal Fields of the United States. Even these discussions are scarcely adequate for they deal only with this country. A general review of the coal resources of the World was made by the International Geological Congress at the Montreal meeting in 1913. These publications are not easily had by the casual reader. Since all other mining is very largely built upon coal a comprehension of the characteristics and location of the principal coal fields is necessary for an understanding of the economics of mining. I am attempting to give in a few further paragraphs some further generalizations on this most interesting subject.

"Technically at least" says David White, Chief Geologist of the U. S.

Geol. Survey, "coal is found in the Ordovician and Cambrian, and probably even in the pre-Cambrian sedimentary series, where it is now represented by bedded graphite." "Well developed coal has been found in the strata of every period since the Silurian." "At present coal is commercially mined (in the United States) from rock of basal Mississippian (Lower Carboniferous), Pennsylvanian (Upper Carboniferous), Triassic, Lower Cretaceous, Upper Cretacceous and Tertiary ages. Some mining for fuel has been done in the Jurassic of Alaska." Thus the formation of coal is shown to be one of the regular geological processes and it has gone on persistently in all times since plant life has existed on the globe. But it is only occasionally that conditions have occurred favorable to the preservation by burying as well as for the formation of peat on a grand scale. It is found that these conditions accompany cycles of world history which have repeated themselves in general terms though not in precise detail. These cycles have a singular bearing on the formation, preservation and exposure of metal deposits also.

While it is a little far-fetched to assert that a study of these broad geologic processes has an intimate bearing on the practical every day pursuits of mining, it is not extravagant to say that it is important to those who wish to have a rational vision of economic resources; or to expect that it will have increasing weight in future explorations for minerals. One may be positive that with industries organizing on an ever more comprehensive scale and governments undertaking projects to harmonize and further them these major geologic facts will have some weight in the locating of manufacturing enterprises and of trade routes. At any rate the subject is interesting.

A century ago as soon as the observations upon the earth's crust had become extensive enough to afford a basis for generalized description, geologists (mainly English at that time) perceived that almost everwhere the sedimentary rocks were separated into several natural groups by abrupt differences of sodidity and attitude. The older, harder and more tilted or contorted rocks they called Primary, an intermediate group they called Secondary, and the more recent and less solidified group the Tertiary. These divisions have been found by the more exhaustive and far reaching researched of all later geologists to be established with about the same definiteness all over the world. Broader and more detailed mapping has since added a fourth and older group obscure to the earlier geologists because less generally exposed, but now established with the same distinctness as the others; so that now the principal sedimentary rocks throughout the world (omitting the recent unconsolidated materials called the Quaternary) are divided into four great groups generally named as follows:

1. The Algonkian or Eozoic containing the recognizable earliest vestiges of life.

2. The Paleozoic, or Old Life group, Primary
3. The Mesozoic, or Middle Life group, Secondary
4. The Cenozoic, or Later Life group, Tertiary

It must be borne in mind that these divisions are not in the least arbitrary or conventional but are clearly marked by nature. Is it not remarkable that the same differences should appear in all the continents and in both hemispheres? What has mud being washed down into a bay in Australia to do with mud in a lake in Montana? What should not the entire series of rocks in Australia be laid down without any reference to what may happen in Montana?

It appears that each of the great groups of stratified rocks represents a cycle of world history in which conditions were comparatively stable and uniform. This does not mean that minor and differential changes did not occur during and throughout these periods; the sea level oscillated more or less just as it is doing at this moment, the processes of erosion brought about their progressive changes at all times; but during these periods these agencies proceeded along the same general lines with regional or local instead of world wide interruptions. In general the progress was toward the wearing down of continental masses, the filling up of depressions, the formation of vast plains and the development of equable climate through the leveling of those barriers, such as lofty mountain ridges, which cause abrupt changes.

In each of the great cycles the last stage was the one favorable to the formation of coal on a great scale. The continents were not only worn down pretty flat but the wearing down of them had filled up the contiguous shallow parts of the ocean, tending to raise the comparative level of the sea. Minor oscillations or warpings of the surface would thus flood or expose large areas of flat lands. The climate being equable was also stable for long periods and an area wet enough to promote the formation of peat would remain so. Thus the conditions, briefly outlined above for the creation of extensive coal deposits reached perfection.

For reasons very dimly, or not at all, understood, these cycles of quiescence and equilibrium were interrupted finally in each case by world wide convulsive movements of the earth's crust, called "Revolutions." These revolutions were not cataclysms in the sense of being sudden and overwhelming disturbances, although they were sufficiently rapid to exterminate innumerable forms of life and to produce great changes in living conditions for both plants and animals. There were no doubt violent earthquakes, always abundant volcanic activity; but in general these revolutions were progressive and differential. The leveling forces were overcome by the forces of upheavel. Great mountain chains and plateaus were thrown up, frequently new ones, the continents in general were raised and took new forms, the ocean beds were deepened

and the sea level retreated. In other words there were immense changes of geography and of climate. Thus in the Southern Hemisphere at the close of the Paleozoic, the mild climate of the coal forming Carboniferous period was succeeded by a formidable refrigeration so that in Permian time ice fields covered portions of South America, Australia and Africa on a scale exceeding that of the recent glacial period of the Northern Hemisphere. This is merely an example.

The revolution having worked itself out, the conditions of comparative equilibrium returned, the erosive forces proceeded again with the work of leveling the uplifted continents; in short a new cycle parallel to but not identical with the old one was under way.

The major coal formations were therefore laid down toward the end of these cycles when the continents were maturely eroded and flattened when climate was equable and stable, and the earth's crust free from disturbance. How far these processes were carried may be gathered from a paragraph or two on the geography of the principal coal formations of North America.

1. The Paleozoic coal fields extend from central Oklahoma to Massachusetts, 1500 miles in a straight line, and from Birmingham, Alabama, to Cedar Rapids, Iowa in greatest breadth, 750 miles. This area contains only the remains of the original deposits, but it gives some idea of the huge low swampy plains, so near sea level that they were repeatedly flooded by gentle oscillations of the level. This area was traversed by rivers which in all probability carried more water than the Mississippi system of today. In fact the lowlands alone, those subject to periodic or occasional overflow by the rivers or the sea, amounted to 1,000,000 square miles in a solid block.

It is not reasonable to suppose that this great tract was all of the same level or that coal was either formed or buried simultaneously over the whole of it; rather that through the progressive changes of sea level the whole area was affected by delta and peat forming conditions which at any given time would form a broad strip immediately back of the sea-coast. The actual deltas probably extended up the rivers hundreds of miles, just as the Mississippi delta of today extends up to Cairo, more than 500 miles in a straight line from the mouth of the river, although for the greater part of that distance the delta covers only a strip on each side side of the river. Whenever the sea level rose those delta strips would retreat inland; whenever the sea level retreated the deltas would advance. Such oscillations did take place, but on the whole the basin was subsiding, for during the period the sediments, containing numerous separate beds of coal accumulated to a depth of several thousand feet, the surface during all the time required for this remaining practically at sea level, varying from one or two hundred feet above to one or two hundred feet below. To get an accurate idea of the appearance of the whole

country within the area mentioned, one needs to do nothing more than to take a look at an uncleared tract near New Orleans. The plants were actually different but to a casual observer they would not have appeared so.

As to the geography outside of this plain we can have only a general idea. Toward the north there was a large area of higher land extending unbrokenly from central Minnesota to Labrador and perhaps beyond. To the southeast in Georgia, South Carolina, North Carolina and Virginia there were, no doubt, land areas, probably large islands of moderate elevation and maturely eroded surface. Toward the west a shallow sea of clear water extended from central Texas, Oklahoma, Kansas and Nebraska. To say that this sea covered the Rocky Mountains is inaccurate. There were no Rocky Mountains to cover. There had been mountains in that region to be sure, but they were different mountains entirely, which had been worn down to a plain and finally immersed in the sea we are talking about. Just where this sea ended toward the north and northwest I do not know, but it certainly covered nearly the whole of New Mexico, the northern part of Old Mexico, the whole of Arizona, southern California and Nevada, and most of Utah, Colorado, Wyoming, Montana, and South Dakota.

Such was, dimly, the Pennsylvanian epoch in North America at the close of Paleozoic time. Marius R. Campbell estimates that the remains of the coal left on these delta plains amounts to 1,088,000,000,000 tons, a trillion, enough to maintain the total present output of the United States for 1500 years. This coal is all of good quality and high rank, varying from bituminous to anthracite. This tract contains more coal by far than the whole continent of Europe, possibly more than the whole of Asia.

The coal fields of Europe are at present the most important, economically speaking, outside of those of North America. The most valuable ones were formed during the same epoch and under a parallel set of conditions. A similar delta plain extended with possible, or probable interruptions from Ireland through Great Britain, Germany, Poland and Russia to the sea of Asov. "The number of workable seams" says Chamberlain and Saulsbury "is large in many places. Thus in Westphalia the number of workable beds is said to be 90. The aggregate (maximum) thickness of the coal in Lancashire is 150 feet, and in Westphalia, 274 feet. Here as elsewhere, beds of marine origin alternate with those which were deposited on land, in marshes, etc."

2. But in North America it is quite a mistake to focus attention too exclusively upon the Paleozoic coalfields. At the end of the next, or Mesozoic, world cycle, in Upper Cretaceous time, there was a still greater coal development. We might repeat almost the same description of continental and climatic conditions but when we come to geography we

must migrate. An immense, flat, subsiding plain so near sea level that it was repeatedly flooded with sea water, extended from the Gulf of Mexico to the Arctic Ocean right over where now are the highest mountains and plateaus of the Rocky Mountain system. The plain terminated in higher land to the eastward on a line from east central Texas to Duluth to Winnipeg; on the west on a line from northwestern Arizona through western Utah and southeastern Idaho, northwestern Montana and eastern British Columbia toward the mouth of the Mackenzie river. This great plain was, therefore, 3500 miles long and up to 1000 miles wide. How much of it was generally under sea water and how much above during the coal forming age is pretty hard to say, but it contains every kind of sediment in great volume, shales, limestones and sandstones. The coal seems to have formed principally in the central portion of this tract, from which we may guess that in this area the erosion of the chief land areas to the west was sufficient to keep the basin nearly full of mud.

Coal was formed on a scale quite equal to that of the Pennsylvanian time. It remains now in New Mexico, Colorado, Utah, Wyoming, and Montana. Mr. Campbell estimates the amount available at a depth of less than 3000 feet at 1400 billion tons of coal of sub-bituminous and bituminous rank with some anthracite. Lying at a depth of from 3000 to 6000 feet he estimates 666 billion tons more, so that the Upper Cretaceous has left us a total of over two million million tons in the United States alone. Possibly a third as much more lies in Canada. Much of this coal is of excellent quality for all purposes, including large amounts suitable for good metallurgical coke.

3. At the end of this wonderful period another world "revolution" occurred, or perhaps more accurately, began. Great geographical changes took place. Australia was permanently separated from Asia. In North America the great Cretaceous trough began to split from end to end along the line of the Front Range of the Rocky Mountains, where blocks of the hard underlying rocks were pushed up through the Cretaceous sediments like flat irons through pan-cakes, raising portions up bodily and crumpling other portions along their flanks. The process of slow subsidence was thus reversed and the great trough humped up in the middle so that the whole became rather a plateau, the eastern half left undisturbed other than by a gentle tilting which made a wide slope of the Great Plains, the western edge of which are in places nearly 8000 feet above sea level. The western half became an area of mountains and plateaus in which the strata are generally disturbed and exposed by faulting and folding, and intruded by volcanic rocks, some of which are enormous batholiths.

But while this post-Cretaceous change was extensive enough at once to produce an abrupt unconformity between those rocks and the succeed-

ing Tertiary formations, it was not extensive enough at first greatly to change the climate. Portions of the great trough remained lowlands and were partially filled by fresh water lakes along which coal formation continued. The largest of these areas was in North Dakota, Montana, and Alberta, where the deposits were on a truly imposing scale. But these coals were never deeply covered by sediments, nor have they been affected by earth movements such as would compress and alter them. They are therefore still lignites, the first stage removed from peat, and are coals of low rank and poor quality. They would be in other countries, however, a wonderful fuel supply. Mr. Campbell estimates in this field 965 billion tons in the United States alone, much of it occurring in thick seams. While this lignite will not make metallurgical coke it will make gas and power. It will not stand transportation or storage very well, but it can be used on the ground for electrical generation, whenever a demand shall rise for it, to good advantage.

But with this exception the Tertiary coals were formed in smaller detached lake basins, or in isolated tracts along the coasts. They occur in Alabama, Mississippi, Tennessee, Arkansas, Louisiana, Texas, California, Oregon, and Washington. The aggregate amount in these fields is great, but in all the Southern States the coal lies in unconsolidated sediments and is a soft low grade lignite. It is only in the state of Washington that a large Tertiary field has been so affected by earth movements as to reach bituminous and sub-bituminous rank. Owing to its position on the great harbor of Puget Sound and to the general scarcity of coal along the Pacific, this is apparently a field of marked economic importance. Mr. Campbell estimates for it some 65 billion tons of which probably about 80,000,000 tons have been mined.

Statistics of Coal Production

Growth of the Coal Industry in the United States—Production of the Different States—Total Production to end of 1917—Prices of Coal—Coal Resources of the Country—Coal Production of the World.

The following discussion on the production, growth, prices, and resources of the coal-mining industry of the United States is taken, with a few comments, from the pamphlet issued by the United States Geological Survey on the Production of Coal in 1917. It is not likely that any other statement to be had gives a truer perspective of the essential features of this business, which may justly be said to be one of the great fundamental elements of the prosperity of the nation. Nothing can be more important than that the public at large shall be acquainted with the real condition of this industry, for it is not unlikely that good public policy will require some changes in the conduct of it, and without the support of public opinion nothing beneficial can be done.

Coal Statistics

"The production in 1917 of 551,791,000 net tons of bituminous coal and of 99,612,000 net tons of Pennsylvania anthracite established new high records in both industries. The increase in the production of bituminous coal over 1916 was 49,271,000 tons, or 9.8 per cent., and in anthracite it was 12,033,000 net tons, or 13.7 per cent. For bituminous coal 1917 marks the third successive year of increase following the depression of 1914; for anthracite it marks the first increase following three years of decreasing output after the previous high record of 1913. During the past several years the development of the anthracite industry has in no way kept pace with that of bituminous coal. In 28 years the production of anthracite slightly more than doubled; that of bituminous coal increased fourfold. The reason for this discrepancy is found primarily in the limited reserves of anthracite as compared with the almost boundless resources of bituminous coal, but is also lies in the fact that anthracite is essentially a domestic fuel whose production has followed more closely the increase in population, whereas bituminous coal is the fuel of industry and has kept pace with industrial expansion in the country. Furthermore, the yearly variations in the production of anthracite are largely the result of weather conditions; but the yearly variations in the production of bituminous coal follow the curve of industrial expansion and depression.

The following discussion, retained from the first edition gives a perspective of the growth of this industry.

"The combined production of anthracite and bituminous coal in the United States in 1907 amounted to a little more than 480,360,000 short tons.

"With an average of 30 cars of coal to the train, and of 50 tons to the car, the number of trains required to transport this product was 320,300, and the combined length of these trains would extend two and two-thirds times around the world at the equator. The hole left in the ground by the extraction of this fuel is equal to 17,585,000,000 cu. ft., and if the entire quantity of coal extracted were built into one cube, it would have the dimensions of 2605 ft., or nearly half a mile on each edge. A rectangular column with a 1000-ft. base to represent the coal production of the United States in 1907 would extend nearly 3.4 miles into the air."

"An interesting fact presented by the statistics of the production of coal in the United States is that in each decade the output has been practically doubled. Up to the close of 1865 the total production had amounted to 284,890,055 tons. In the decade from 1866 to 1875, inclusive, the production amounted to 419,425,104 tons, making the total production up to the close of 1875, 704,315,159 tons. In the following decade, from 1876 to 1885, inclusive, the production amounted to 847,760,319 tons, something more than double the total production up to the beginning of that decade. At the close of 1885 the total production amounted to 1,552,075,487 tons and the production for the 10 years ending with 1895 was 1,586,098,641 tons, and the total production at the close of 1895 amounted to 3,138,174,119 short tons. In the decade ending December 31, 1905, the total production amounted to 2,832,402,746 short tons, and the grand total from the beginning of coal mining amounted to 5,970,576,865 short tons. The average annual production from 1896 to 1905 was 283,240,275 short tons, compared with which the average production in 1906 and 1907 (447,260,351 short tons) shows an increase of 164,020,076 tons, or 58 per cent.

"This great increase in the production of coal, when considered with the in-

crease in the population, furnishes some further interesting comparisons. Going back for a period of a little over 50 years, or to the middle of the last century, and comparing the statistics of coal production with the increased population, it is found that in 1850, according to the United States census for that year, the production of coal amounted to 6,445,681 tons, when the population of the country amounted to 23,191,876 persons. The per capita production of coal in that year is thus seen to have been 0.278 ton. In 1860, or 10 years later, the population was 31,443,321 persons, and the coal production amounted to 16,139,736 tons, or an average of 0.514 ton per person. At the census of 1870 the population of the United States amounted to 38,558,371; the coal production in that year amounted to 36,806,560 short tons, a per capita average of 0.96 ton. Ten years later, when the population was 50,189,209, the coal output amounted to 76,157,944 short tons, or 1.52 tons per capita. In 1890 the population had grown to 63,069,756, an increase of 25 per cent. over 1880, while the coal production had grown to 157,770,963 short tons, or a per capita output of 2.52 tons. At the taking of the Twelfth Census, in 1900, the increase in population amounted to 22 per cent., the total number of persons reported being 76,303,387, while more than 70 per cent. had been added to the coal production, with a total of 269,684,027 short tons, or an average of 3.53 tons for each inhabitant. In other words, while the population from 1850 to 1900 showed an increase of 230 per cent. the production of coal increased 4084 per cent. The Director of the Bureau of the Census, Hon. S. N. D. North, estimates the population of the United States on June 1, 1907, at about 85,500,000 persons, making the per capita production in that year 5.6 tons; that is, in less than 60 years the per capita production of coal in this country has increased from a little more than a quarter of a ton to 5½ tons. It is true that in the earlier years the proportion of wood used for fuel was larger than it is to-day, but the actual consumption of wood at this time is little, if any, less than it was 50 years ago, and is probably greater. It must also be remembered that in addition to the great increase in the consumption of coal per head of population there has been a great increase in the use of oil for fuel purposes, while natural gas still remains an important factor in this regard.

"The total number of men employed in the coal mines of the United States in 1907 was 680,492, against 640,780 in 1906 and 626,035 in 1905. Of the total number of men who were employed in 1907, 167,234 were employed in the anthracite mines of Pennsylvania, while the bituminous and lignite mines gave employment to 513,258 men. In 1906 the anthracite mines gave employment to 162,355 men and in 1905 to 165,406 men. The bituminous workers numbered 478,425 in 1906 and 460,629 in 1905. The average number of days worked in the anthracite region in 1907 was 220, against an average of 195 in 1906 and 215 in 1905. The bituminous mines worked an average of 234 days in 1907, 213 days in 1906, and 211 days in 1905.

The foregoing statements were written in 1908 but they convey the essential facts as well as if they were written in 1919. The tables of production are, however, changed to show the figures for more recent years. Some remarks may be of interest.

It appears that while the production of coal per capita is still increasing in this country, it is not doing so at the former rate. The increase between 1897 and 1907 was from about 2.77 tons per capita to about 5.6

tons per capita; from 1907 to 1917 the increase was only from 5.6 to 6.5. It might appear from this that the desire of the population for fuel is nearly satisfied. We may reckon with certainty that a time will come when the consumption of coal will increase only in proportion to the increase of population.

The same facts are shown by the total output of the country to date. It will be remembered that up to 1907 the production was doubling each decade so that between 1897 and that year it was nearly equal to the entire production of the country previous to 1907. From 1907 to 1917 the production was only 75 per cent. of the previous production.

Still more noticeable is the failure of the number of men employed in coal mining to increase at the former rate. In 1897 the number was 397,000; in 1907 it was 680,000, an increase of 283,000 for the decade; but in 1917 the number had risen only to 750,000, an increase of only 70,000 for the decade.

The statistics show a remarkable uniformity of conditions in the coal industry up to the end of 1915. In that year the value of all coal at the mines was estimated by the U. S. Geological Survey at $1.29 per ton, almost exactly the same as shown by the tables for the years 1903–1907.

THE WORLD'S PRODUCTION OF COAL IN SHORT TONS

Country	1914	1915	1916	1917	1918
United States	513,525,477	531,619,487	590,098,175	651,402,374	678,211,904
Canada	13,594,984	13,269,023	14,461,678	14,046,759	14,979,213
Chile	1,198,000	1,291,000	1,563,000		
Peru	312,897	318,563	357,346	396,132	
Austria-Hungary	(*d*)53,396,400	(*d*)52,679,712	50,801,602	42,278,850	35,738,082
Belgium	18,423,897	15,627,858	16,458,816	18,587,942	15,308,301
France	33,360,885	19,908,892	23,670,000	31,847,000	30,864,000
Germany	270,594,952	259,139,786	272,099,000	(*c*)281,429,000	273,930,000
Great Britain	297,698,617	283,570,560	287,110,153	278,319,149	255,040,328
Holland	2,160,543	2,534,284	2,879,000	3,370,000	5,277,813
Italy	861,265	1,042,748	1,439,538	1,898,334	2,393,531
Russia	36,414,560	31,158,400	28,962,724	(*a*)30,047,000	
Spain	4,897,360	5,414,475	6,055,727	6,261,124	7,897,319
Sweden	404,143	454,432	457,262	487,914	445,874
China	(*a*)10,199,200	(*a*)19,800,000	(*a*)24,000,000		
Dutch East Indies	440,905	485,158	539,816	(*a*)910,000	(*a*) 1,000,000
India	18,430,974	19,156,404	19,324,826	20,398,468	23,209,104
Indo-China	608,660	708,000	(*a*)856,000		
Japan	21,700,572	22,596,750	22,189,969	29,220,897	(*a*) 30,600,000
Union of So. Africa	9,461,674	9,275,083	11,208,400	11,628,870	11,937,682
Rhodesia	391,394	458,934	491,532	614,856	550,243
New South Wales	11,663,865	10,582,889	1,262,420	9,288,011	10,160,000
New Zealand	2,548,664	2,208,624	2,527,991	2,316,629	
Queensland	1,180,825	1,147,186	1,016,654	1,174,290	1,101,176
Tasmania	68,130	66,000	62,244	71,021	67,386
Western Australia	357,515	321,066	337,709		
Victoria	691,640	588,104	463,074		
Total	(*c*)1,332,000,000	(*c*)1,312,000,000	(*c*)1,401,000,000	(*c*)1,476,000,000	(*a*) 1,468,000,000

(*a*) Estimated. (*c*) Approximate. (*d*) Hungarian production estimated at 10,000,000 short tons.

NOTE.—This table is based on a compilation of the U. S. Geological Survey, supplemented by some later statistics. Most of the figures given are obtained from other sources and represent the best information available at this writing.

PRODUCTION OF COAL IN THE UNITED STATES IN SHORT TONS

State	1916		1917		1918
	Quantity	Total value	Quantity	Total value	Quantity (*e*)
Alabama	18,086,197	$24,859,831	20,068,074	$45,616,992	21,280,000
Alaska	13,073	52,317	53,955	265,317	70,000
Arkansas	1,994,915	3,836,845	2,143,579	5,492,777	2,228,000
California and Idaho	7,240	15,367	6,423	14,791	6,000
Colorado	10,484,227	16,964,104	12,483,336	27,669,129	12,485,000
Georgia	173,554	310,093	119,028	301,391	101,000
Illinois	66,195,336	82,457,954	86,199,387	162,281,822	91,263,000
Indiana	20,093,528	25,507,246	26,539,329	52,940,106	27,325,000
Iowa	7,260,800	13,530,383	9,965,830	21,096,408	8,240,000
Kansas	6,881,455	12,252,723	7,184,975	16,618,277	7,292,000
Kentucky	25,393,997	30,193,047	27,807,971	60,297,653	29,690,000
Maryland	4,460,046	6,947,623	4,745,924	11,667,852	4,759,000
Michigan	1,180,360	2,653,182	1,374,805	4,426,314	1,385,000
Missouri	4,742,146	9,044,505	5,670,549	13,755,864	5,605,000
Montana	3,632,527	6,286,197	4,226,689	8,919,136	4,276,000
New Mexico	3,793,011	5,580,369	4,000,527	7,455,166	4,241,000
North Dakota	644,912	946,082	790,548	1,425,750	813,000
Ohio	34,728,129	40,150,907	40,748,734	100,897,148	46,464,000
Oklahoma	3,608,011	7,525,427	4,386,844	12,335,413	4,785,000
Oregon	42,592	113,976	28,327	95,663	39,000
Pennsylvania, bituminous	170,295,423	221,685,175	172,448,142	421,268,808	183,712,000
South Dakota	8,886	18,021	8,042	23,346	7,000
Tennessee	6,137,449	7,522,445	6,194,221	13,592,998	6,916,000
Texas	1,987,503	3,092,663	2,335,815	4,177,608	2,260,000
Utah	3,567,428	5,795,944	4,125,230	8,531,382	5,535,000
Virginia	9,707,474	10,261,424	10,087,091	20,125,713	10,100,000
Washington	3,038,588	6,907,428	4,009,902	10,727,362	4,056,000
West Virginia	86,460,127	102,366,092	86,441,667	200,659,368	91,350,000
Wyoming	7,910,647	12,239,707	8,575,619	16,593,283	9,600,000
Total bituminous	502,519,682	665,116,077	551,790,563	1,249,272,837	585,883,000
Pennsylvania, anthracite	87,578,493	202,009,561	99,611,811	283,650,723	98,826,000
Grand total	590,098,175	876,125,628	651,402,374	1,532,923,560	684,709,000

(*e*) Estimated.

Coal Produced in the United States in 1917

State	Loaded at mines for shipment (net tons)	Sold to local trade and used by employees (net tons)	Used at mines for steam and heat (net tons)	Made into coke at mines (net tons)	Total quantity (net tons)	Total value	Average value per ton	Number of employees: Underground	Number of employees: Surface	Number of employees: Total	Average number of days worked
Alabama	15,272,716	508,398	641,733	3,645,227	20,068,074	$45,616,992	$2.27	22,925	5,461	28,386	273
Alaska	....	53,955	....	....	53,955	265,317	4.92	(a)	(a)	(a)	(a)
Arkansas	2,009,408	59,104	75,067	....	2,143,579	5,492,777	2.56	3,135	863	3,998	187
California and Idaho	2,800	3,383	240	....	6,423	14,791	2.30	11	6	17	173
Colorado	9,770,529	450,392	304,492	1,957,923	12,483,336	27,669,129	2.22	11,285	2,946	14,231	263
Georgia	37,855	1,284	7,200	72,689	119,028	301,391	2.53	205	76	281	269
Illinois	80,283,345	3,541,792	2,374,250	....	86,199,387	162,281,822	1.88	75,085	9,005	84,090	243
Indiana	24,991,177	905,601	642,551	....	26,539,329	52,940,106	1.99	22,664	3,864	26,528	221
Iowa	7,954,466	784,970	226,394	....	8,965,830	21,096,408	2.35	12,672	1,594	14,266	251
Kansas	6,838,507	161,004	185,464	....	7,184,975	16,618,277	2.31	8,816	1,864	10,680	216
Kentucky	25,674,798	893,580	639,977	599,616	27,807,971	60,297,653	2.17	28,162	6,764	34,926	214
Maryland	4,582,436	104,578	58,910	....	4,745,924	11,667,852	2.46	4,696	1,223	5,919	254
Michigan	1,244,795	82,045	47,965	....	1,374,805	4,426,314	3.22	2,154	252	2,406	254
Missouri	4,942,689	576,079	151,781	....	5,670,549	13,755,864	2.43	7,680	1,988	9,668	240
Montana	3,882,919	176,066	167,704	....	4,226,689	8,919,136	2.11	3,338	811	4,149	268
New Mexico	2,927,954	44,636	36,449	991,488	4,000,527	7,455,166	1.86	3,191	935	4,126	321
North Dakota	559,571	196,900	34,077	....	790,548	1,425,750	1.80	619	202	821	255
Ohio	37,462,479	2,534,344	751,281	630	40,748,734	100,897,148	2.48	38,569	6,940	45,509	210
Oklahoma	4,152,162	45,492	189,190	....	4,386,844	12,335,413	2.81	7,017	1,478	8,495	211
Oregon	13,736	9,087	5,504	....	28,327	95,663	3.38	77	27	104	251
Pennsylvania (bituminous)	128,965,937	5,275,741	3,499,727	34,706,737	172,448,142	421,268,808	2.44	143,687	30,281	173,968	261
South Dakota	647	7,395	....	....	8,042	23,346	2.90	34	....	34	154
Tennessee	5,170,586	135,348	164,698	723,589	6,194,221	13,592,998	2.19	8,053	2,368	10,421	241
Texas	2,292,358	14,102	49,355	....	2,355,815	4,177,608	1.77	3,683	692	4,375	263
Utah	3,292,758	77,028	86,128	669,316	4,125,230	8,531,382	2.07	2,569	916	3,485	219
Virginia	7,733,626	173,535	145,231	2,034,699	10,087,091	20,125,713	2.00	8,607	2,561	11,168	273
Washington	3,614,329	71,606	166,399	157,568	4,009,902	10,727,362	2.68	4,072	1,240	5,312	271
West Virginia	77,996,698	2,494,393	1,194,951	4,755,625	86,441,667	200,659,368	2.32	69,155	19,267	88,422	225
Wyoming	8,179,694	125,484	270,441	....	8,575,619	16,593,283	1.93	6,024	1,334	7,358	246
Total bituminous	469,850,975	19,507,322	12,117,159	50,315,107	551,790,563	1,249,272,837	2.26	498,185	104,958	603,143	243
Pennsylvania (anthracite)	86,788,848	2,382,362	10,440,601	....	99,611,811	283,650,723	2.85	109,989	44,185	154,174	285
Grand total	556,639,823	21,889,684	22,557,760	50,315,107	651,402,374	1,532,923,560	2.35	608,174	149,143	757,317	251

[a] Not available.

"The increase in production in 1917 compared with 1916 was not shared equally by all producing fields. The increase was mainly in the fields west of the Pennsylvania-Ohio State line. The only States to record decreases were Georgia, Oregon, South Dakota, and West Virginia, all of which, with the exception of West Virginia, are of minor importance. The largest and most significant increases were in Illinois, 30 per cent.; Indiana, 32 per cent.; and Ohio, 17 per cent.

"There were no changes in the rank of the larger coal-producing States in 1917. Iowa and Wyoming exchanged positions, Iowa leading Wyoming in 1917. New Mexico dropped back from sixteenth place in 1916 to twentieth place in 1917; Alaska from twenty-eighth, or lowest position, in 1915, rose in two years to twenty-sixth place.

"Abundant and efficient labor is essential to the maximum production of coal. For the country as a whole the average output per man per day has not yet reached 4 net tons of bituminous coal, and of anthracite an average output of 2.50 net tons per man per day has been recorded in only one year in the last seventeen. To obtain the enormous total of 651,400,000 tons of coal in 1917 more than 757,000 men, not including coke workers and office force, were employed in and about the mines, a record exceeded in only one previous year, 1914, when the total was 763,185 men.

"Considered separately, the bituminous and anthracite industries presented contrasting conditions in 1917. The supply of labor in the bituminous fields was the largest recorded—603,000 men—a substantial increase compared with 561,100 in 1916 and 583,500 in 1914. In the anthracite regions the number of men employed was 154,174, compared with 159,869 in 1916, and was the lowest number recorded since 1903.

"The most striking feature presented by the statistics of labor for 1917 is the relatively larger increase in the number of outside or surface employees in comparison with the underground labor in both bituminous and anthracite mining. In the bituminous mines the increase in the total men employed was 7.5 per cent.; the underground employees, representing 79 per cent. of the total in 1917, increased only 5 per cent., compared with 1916, whereas the surface labor increased 21 per cent. The same was true in the anthracite mines, for although the total number of men decreased 3.6 per cent., inside labor decreased 5.7 per cent. and outside labor increased 2.3 per cent.

"The reason for this difference is found both in the circumstances surrounding the labor market and in the greatly increased demand for coal that prevailed in 1917. The demand for coal was so great and the prevailing market price of coal so good that operators exerted every effort to increase their capacity and output. The most certain way to increase capacity is to put on more men, and, as experienced inside men were more difficult to obtain than day laborers, the outside force was augmented more rapidly and out of proportion to the normal requirements. Under the pressure from increased output the operators, apparently without regard to its effect in costs, added labor of any description.

"In the coal industry the productive labor is that done underground. Except for very small percentage of the output obtained from steam-shovel pits, the coal is produced by the men inside. The average output per man per day (all labor considered) in 1917 was 3.77 tons of bituminous coal, a decrease of 3.3 per cent. from 3.90 tons in 1916. If the largely increased number of total men in 1917

had worked no more days in 1917 than were worked in 1916 they would have produced, at the average daily rate per man, nearly 30,000,000 tons of bituminous coal less than they did. In other words, the decrease in the average effectiveness of bituminous mine labor in 1917 largely offset the increase in the supply of labor, and the large gain in output was the result of the greater number of days worked. Stated in another way, 7.5 per cent. more men working 5.7 per cent. more days produced in 1917 only 10 per cent. more coal, because they were only 97 per cent. as effective as in 1916.

"The record for the anthracite industry contrasted with that of the bituminous industry shows a decrease in men but an increase in average daily output from 2.16 to 2.27 net tons, or 5 per cent., a record not equaled or exceeded since 1908. The anthracite mines, not hampered like the bituminous mines by lack of cars, were worked 285 days in 1917, compared with 253 days in 1916, 230 days in 1915, and 257 days in 1913, the previous high record.

Average Value per Ton of Coal at the Mines since 1908

State	1908	1909	1910	1911	1912	1913	1914	1915	1916	1917	Advance in 1917
Alabama	$1.26	$1.19	$1.25	$1.27	$1.29	$1.31	$1.34	$1.28	$1.37	$2.27	+$0.90
Alaska	(a)	(a)	(a)	(a)	(a)	(a)	(a)	(a)	4.00	4.92	+ .92
Arkansas	1.68	1.48	1.56	1.61	1.71	1.76	1.72	1.79	1.92	2.56	+ .64
California	b3.19	2.21	b2.74	b2.00	2.33	b3.54	c2.85	bc2.54	c 2.12	c2.30	+ .18
Colorado	1.41	1.33	1.42	1.45	1.49	1.52	1.66	1.58	1.62	2.22	+ .60
Georgia	1.38	1.41	1.46	d1.49	d1.49	1.41	e1.44	1.72	1.79	2.53	+ .74
Idaho	4.02	4.27	3.92	f2.68	f3.14	2.43	(c)	(c)	(c)	(c)	(c)
Illinois	1.05	1.05	1.14	1.11	1.17	1.14	1.12	1.10	1.25	1.88	+ .63
Indiana	1.06	1.02	1.13	1.08	1.14	1.11	1.10	1.10	1.27	1.99	+ .72
Iowa	1.63	1.65	1.75	1.73	1.80	1.79	1.79	1.78	1.86	2.35	+ .49
Kansas	1.49	1.44	1.16	1.53	1.62	1.67	1.64	1.66	1.78	2.31	+ .53
Kentucky	1.01	.94	.99	.99	1.02	1.05	1.02	1.01	1.19	2.17	+ .98
Maryland	1.17	1.11	1.12	1.11	1.18	1.24	1.27	1.28	1.56	2.46	+ .90
Michigan	1.81	1.79	1.91	1.78	1.99	1.99	1.99	2.05	2.25	3.22	+ .97
Missouri	1.64	1.65	1.79	1.72	1.76	1.73	1.73	1.73	1.91	2.43	+ .52
Montana	1.96	1.97	1.82	1.79	1.82	1.74	1.75	1.62	1.73	2.11	+ .38
New Mexico	1.37	1.29	1.39	1.44	1.42	1.46	1.61	1.44	1.47	1.86	+ .39
North Dakota	1.63	1.56	1.49	1.43	1.53	1.52	1.52	1.45	1.49	1.80	+ .31
Ohio	1.06	.99	1.05	1.03	1.07	1.10	1.13	1.08	1.33	2.48	+ 1.15
Oklahoma	2.03	2.00	2.22	2.05	2.14	2.05	2.06	2.01	2.09	2.81	+ .72
Oregon	2.74	2.69	3.48	2.32	2.60	2.53	2.78	2.84	2.68	3.38	+ .70
Pennsylvania (bituminous)	1.01	.94	1.02	1.01	1.05	1.11	1.07	1.06	1.30	2.44	+ 1.14
South Dakota	......	......	......	......	......	1.96	1.73	1.55	2.03	2.90	+ .87
Tennessee	1.15	1.09	1.11	1.12	1.14	1.14	1.14	1.13	1.23	2.19	+ .96
Texas	1.80	1.72	1.67	1.66	1.67	1.77	1.69	1.65	1.56	1.77	+ .21
Utah	1.68	1.66	1.68	1.69	1.67	1.65	1.59	1.58	1.62	2.07	+ .45
Virginia	.91	.89	.90	.91	.96	1.01	1.01	.98	1.06	2.00	+ .94
Washington	2.21	2.54	2.50	2.29	2.39	2.38	2.20	2.17	2.27	2.68	+ .41
West Virginia	.95	.86	.92	.90	.94	1.01	.99	.97	1.18	2.32	+ 1.14
Wyoming	1.62	1.55	1.55	1.56	1.58	1.56	1.55	1.46	1.55	1.93	+ .38
Total bituminous	1.12	1.07	1.12	1.11	1.15	1.18	1.17	1.13	1.32	2.26	+ .94
Pennsylvania anthracite	1.90	1.84	1.90	1.94	2.11	2.13	2.97	2.07	2.30	2.85	+ .55

a Included with California. b Includes Alaska.

c California includes Idaho and Nevada in 1914 and 1915; Idaho in 1916 and 1917.

d Includes North Carolina.

e Average for total output, including refuse from washery. The average, excluding refuse, was $1.71. f Includes Nevada.

Average Value per Net Ton of Coal at the Mines in the United States for 38 Years

Year	Anthracite	Bituminous	Year	Anthracite	Bituminous
1880	$1.47	$1.25	1899	$1.46	$0.87
1881	2.01	1.12	1900	1.49	1.04
1882	2.01	1.12	1901	1.67	1.05
1883	2.01	1.07	1902	1.84	1.12
1884	1.79	0.94	1903	2.04	1.24
1885	2.00	1.13	1904	1.90	1.10
1886	1.95	1.05	1905	1.83	1.06
1887	2.01	1.11	1906	1.85	1.11
1888	1.91	1.00	1907	1.91	1.14
1889	1.44	0.99	1908	1.90	1.12
1890	1.43	0.99	1909	1.84	1.07
1891	1.46	0.99	1910	1.90	1.12
1892	1.57	0.99	1911	1.94	1.11
1893	1.59	0.96	1912	2.11	1.15
1894	1.51	0.91	1913	2.13	1.18
1895	1.41	0.86	1914	2.07	1.17
1896	1.50	0.83	1915	2.07	1.13
1897	1.51	0.81	1916	2.30	1.32
1898	1.41	0.80	1917	2.85	2.26

Total Production of Coal in the United States from 1807 to the Close of 1917, in Short Tons

Pennsylvania, anthracite.	2,813,702,882	Michigan	27,906,044
Pennsylvania, bituminous	3,380,627,056	Georgia	10,018,874
Virginia	132,164,477	California	5,153,264
Kentucky	303,075,049	West Virginia	1,109,282,513
Illinois	1,234,329,819	Colorado	215,124,810
Ohio	799,433,305	Wyoming	148,256,505
Missouri	138,328,740	Kansas	157,448,653
Indiana	331,912,239	Utah	48,157,243
Alabama	323,629,988	Oklahoma (Indian Territory)	75,151,212
Tennessee	147,755,654	Oregon	2,327,529
Iowa	217,894,892	Montana	54, 854,203
Arkansas	44,186,728	New Mexico	57,006,773
North Carolina	477,125	Texas	35,405,289
Maryland	193,173,673	North Dakota	7,883,739
Washington	77,001,845	Miscellaneous	39,135,327
Total			12,130,805,450

The following chart and tables are a brief abstract from U. S. Geological Survey Professional Paper 100–A, "The Coal Fields of the United States," by Marius R. Campbell.

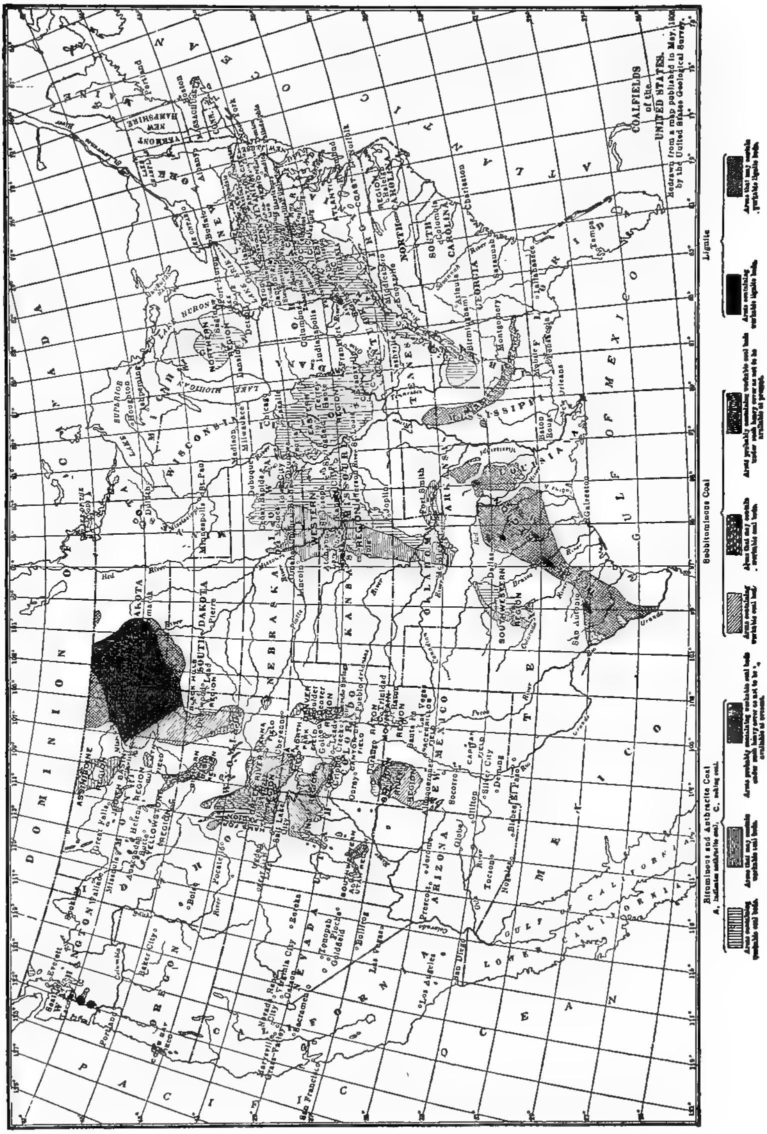

COALFIELDS
of the
UNITED STATES.
Bituminous and Anthracite Coal
Subbituminous Coal
Lignite

FIG. 1.

Province, region, or field	Estimate of the original tonnage			
	Anthracite and semianthracite	Semibituminous coal	Bituminous coal	Sub-bituminous coal
Eastern province	21,150,000,000	48,637,200,000	503,011,600,000	....
Interior province	400,000,000	1,226,300,000	528,273,000,000	....
Gulf province	....	....	45,553,000,000	284,548,400,000
Rocky Mountain province	503,000,000	....	354,640,000,000	713,282,700,000
Pacific coast province	....	....	11,439,000,000	53,458,900,000
Total	22,053,000,000	49,863,500,000	1,442,916,600,000	987,514,000,000

Province, region, or field	Lignite	Total coal of all ranks	Coal below surface from 3000 to 6000 feet	Production in 1913
Eastern provinces	....	572,798,800,000	....	422,262,001
Interior province	....	529,899,300,000	....	115,227,977
Gulf province	23,090,000,000	23,090,000,000	....	1,181,156
Rocky Mountain province	964,424,000,000	1,294,525,400,000	....	14,588,625
Pacific coast province	....	1,068,425,700,000	666,600,000,000	12,736,878
	....	64,897,900,000	....	3,963,582
Total	1,051,290,000,000	3,553,637,100,000	666,600,000,000	569,960,219

Province, region, or field	Production in 1914	Total production to end of 1914	Estimated supply within 3000 feet of surface
Eastern province	375,634,969	7,776,730,234	561,032,000,000
Interior province	108,704,258	2,014,902,039	527,874,000,000
Gulf province	1,105,613	10,509,960	23,074,000,000
Rocky Mountain province	13,134,207	236,937,310	1,294,180,000,000
Pacific coast province	11,816,078	204,697,756	1,067,609,000,000
	3,130,352	114,929,105	64,785,000,000
Total	513,525,477	(b)10,357,706,404	3,538,554,000,000

(b) A total production of 10,357,706,404 tons is assumed to mean an exhaustion of about 50 per cent. more, or 15,083,100,000 tons.

CHAPTER VII

COST OF MINING COAL

FACTORS GOVERNING COSTS—PRICE OF WAGES A RESULT OF EFFICIENCY—PRICE AND COST OF COAL IN VARIOUS STATES—ESTIMATE OF COST FOR VARIOUS PLACES—PITTSBURG COAL COMPANY—CAPITAL CHARGES—DETAILS OF COST OF COKING COAL IN VIRGINIA-ILLINOIS FIELD—COKE MANUFACTURE AND ANTHRACITE MINING—COST OF COKE—COST OF ANTHRACITE—PHILADELPHIA AND READING COAL AND IRON COMPANY—CHANCE'S CHART OF COSTS ACCORDING TO THICKNESS—PUBLIC POLICY IN COAL MINING—CAUSES OF WASTE—LIMITATION OF WASTE A QUESTION OF THE VALUE PUT UPON COAL—DESIRABILITY OF EXTENSIVE CONSOLIDATIONS—CAPITAL REQUIRED FOR COAL MINING EXPANSION—RECENT CHANGES.

The cost of coal to the consumer depends on two elements that vary widely: (1) Mining and (2), Transportation; but since the effect of the latter is self-evident, I do not propose to discuss it.

Factors that Influence Cost of Mining.—I. The cost of mining coal depends, in my judgment, upon the following factors:

(*a*) The thickness of the seam.

(*b*) The purity of the coal in the seam.

(*c*) The regularity of the seam.

(*d*) The geological attitude as regards angle of dip, occurrence of faults, etc.

(*e*) The climate, cost of living, etc.

(*f*) The depth.

(*g*) The amount of water to be pumped.

(*h*) The solidity of the roof.

(*i*) The presence of gas, dust, or other elements of danger.

(*j*) Topography of the surface.

Some other factors may influence the cost in a minor degree; such as the hardness of rock encountered in development work, hardness of coal, cost of supplies, etc.

It will be noted that I have mentioned only natural conditions, leaving out the factor that many would be inclined to place first on the list—the rate of wages. I do not believe that this is a factor at all. The price of labor is determined by the natural factors. It is an effect not a cause, in the economy of mining. If we have two neighboring districts with the same natural advantages, but in which the rates of of wages are different, that difference is apparent, not real. The difference

will be equalized by the supply and demand for labor as automatically as water runs down hill. If a mine pays lower wages than its neighbor it will have poorer men; if other conditions are the same, the cost will be the same. You cannot change this natural law; it is like the force of gravity.

Labor Cost and Wages.—I hope that no one will understand this dictum to mean that where natural conditions are the same, the wages will be the same, or that the cost of labor will be the same; on the contrary, these things vary a good deal. Management, scale of operations, appliances of all kinds vary, or may vary, almost without limit among various enterprises. These factors help to establish wages and labor costs; they are quite independent both of natural conditions and of labor conditions, and have to do with the success or failure of enterprises. They introduce variations in cost that are, or may be, equal to the margin of profit that there is in the business.

How Labor Costs may Differ with Same Rate of Wages.—To elaborate a little, let us suppose that Smith and Jones are two rival operators in neighboring coal mines in which the natural conditions are exactly the same and in which coal is salable at $1 per ton. There are only two mines in the district and each can produce twice its actual tonnage. Smith is a good operator, with sufficient capital, equipment, development and ventilation. He can mine coal for 60 cents per ton. Jones is a poor operator, and his mine is poorly opened. It costs him $1 per ton to produce coal. It is obvious that the successful and opulent Smith has the decision as to how great a difference there shall be in labor costs in that district. He can prevent Jones from making a profit, and can close him down by selling coal under $1 per ton, which is Jones' cost. It is obvious that the difference between labor costs here will be approximately as 6 is to 10. This is not due to the rate of wages; it is just the difference between Smith and Jones.

How Wages may Differ and Costs be the Same.—Now let us suppose that Smith and Jones are 2000 miles apart and each sells his coal at a point midway between them with equal transportation costs. Smith can supply the market and so can Jones, and each wants to sell all he can, and can produce all he can sell. Smith can sell without loss as low as 60 cents per ton. Jones, if he pays as much wages as Smith, cannot sell for less than $1. Neither Jones nor his employees know anything of Smith's superior methods and appliances, and they have no means of living except by selling coal. Obviously under these conditions there is only one thing to do—work for less money. So Jones fixes his wages at 60 per cent. of Smith's wages and continues business. This rate is fixed by the efficiency of Jones as against Smith. His men get just what they earn. In other words, the final result is exactly the same as if each laborer were in business for himself.

Actual Costs.—Returning now to the natural factors that govern the cost of coal mining, we find that their number and importance is very considerable, and if all coal were to be mined we should have enormous differences of cost. As a matter of fact, these great difference do not at present exist because the commercial conditions of the country cause the elimination of all mines except those favorable for cheap working. This results from the fact that there is in this country, according to the U. S. Geological Survey, 2,000,000,000,000 tons of coal of all kinds easily accessible. This coal is spread over an area of 500,000 sq. m., and may be attacked at many thousand favorable points. The unfavorable seams will have to wait to be worked after the better ones are exhausted.

Price of Coal at Mines.—According to the excellent review of the "Production of Coal" for 1907, published by the U. S. Geological Survey, the extreme variation in the price of coal at the mines in the various States is only from 99 cents in West Virginia to $4.10 in Idaho. The last figure is for only 7500 tons and doubtless represents a case where an isolated but unfavorable seam may be worked because high transportation charges prevent the introduction of coal from other places. Leaving out such abnormal cases and considering only States where the output reaches 1 per cent. of the production of the country, we find that the price of bituminous coal at the mines varies only between 99 cents for West Virginia to $1.68 for Arkansas. Pennsylvania anthracite is valued at $1.91, but I shall explain later that the cost of anthracite is radically different from that of bituminous coal and no comparison should be made except with very careful explanation.

Selling and Cost Prices of Bituminous Coal—Run of Mine

	1903	1904	1905	1906	1907
U. S. price..........	$1.24	$1.10	$1.06	$1.11	$1.14
Cost................	1.11	0.99	0.95	1.00	1.00

United States average price for 5 years, $1.13; estimated cost, $1.00

	1907 price		Estimated cost.
Pennsylvania..........................	$1.03	Appalachian field.	$0.93
West Virginia..........................	0.99		0.90
Maryland..............................	1.20		1.08
Virginia................................	1.02		0.91
Kentucky..............................	1.06		0.95
Illinois................................	1.07	Illinois field.	0.96
Alabama..............................	1.29	Southern field.	1.17
Arkansas..............................	1.68	Ozark field.	1.50
Colorado..............................	1.40	Rocky Mountain field.	1.26
Wyoming..............................	1.56		1.40
Utah..................................	1.52		1.37
New Mexico............................	1.46		1.31
Washington............................	2.09	Puget Sound field	1.88
Michigan..............................	1.80	Michigan field.	1.62

It is probable that the figures of average price of coal at the mines give the best general idea to be had of the cost of mining throughout the country. The price, of course, exceeds the cost, but it can be confidently asserted that the difference is not over 10 to 15 cents per ton, if we consider the whole output of States. Within given fields there must be considerable variation; some mines working cheaply and with large profits, while others have no profits at all, and some, if all capital charges were correctly made against them, would be found running at a loss. But it is quite obvious that the entire industry cannot run at a loss and that the average complete cost must fall inside the average selling price. It is difficult to get specific figures that will illuminate the general subject as accurately as the broad figures published by the Survey, and I doubt if we can form a better idea of average costs than by assuming them to be 90 per cent. of the selling price. This assumption gives us the preceding for bituminous coal.

These costs are intended to be complete, that is, to cover both operating and capital charges. I shall endeavor to give some reasons for believing them to be fairly accurate, but first let me disavow any intention of applying them to any particular property or district. It would be more enlightening, possibly, to take some detailed statements of costs and compare and digest them. But such statements are hard to get and I must confess that those I have been able to secure are open to grave question as to their accuracy. For instance, I have the statements of a coal company operating three different mines. Detailed statements of operating costs for each month for each mine are given for a period of years. The aggregate tonnage and total operating cost may be figured out only with great labor. To get five years' operation averaged, I should have to combine 180 different cost statements. If this were necessary to secure the facts, one might be heroic enough to do it, but, after all, it would only give the results of an insignificant fragment of a single field and a single management. But far worse than this, after making this compilation, I should still doubt its accuracy because a single glance at the balance sheet reveals the fact that in mining 1,000,000 tons of coal, $350,000 has been added to capital charges. The writing off of such charges is a matter of judgment, based on familiarity with the property itself. I cannot possibly supply either the time or the experience required to form a judgment of my own as to this rate of depreciation, and yet, in a business of narrow margin like that of bituminous coal, it is a matter of great importance whether 1 cent, or 5 cents, or 15 cents per ton must be added for depreciation.

It is interesting to note that E. V. d'Invilliers, in his article on "Estimated Costs of Mining and Coking" (*Trans.* A. I. M. E., Vol. XXXV, 1905) shares the same difficulty in arriving at true costs for coal-mining operations. He expresses himself as follows:

"The cost of coal delivered to an oven, and the cost of the manufactured product, depends largely upon individual judgment or practice, and on general management. Therefore, without having access to the accounts of a number of individual mines, it is not possible to do more than approximate the average regional cost of mining coal or manufacturing coke.... For, though each plant in a district may be mining upon the same scale of wages, the computation of net mining costs may differ to a considerable extent in two adjoining plants, due to different methods of bookkeeping, to a difference of opinion as to what items are properly chargeable to mining account and to capital account, or to physical difference at the two mines."

Mr. d'Invilliers goes on to estimate the real cost of mining and coking at Connellsville and at Reynoldsville, Penn., the first a slope mine, largely self-draining, on a seam capable of producing 9000 gross tons (10,000 short tons) to the acre; the second a shaft mine where considerable pumping will be required and capable of producing 7200 gross tons (8000 short tons) per acre. His estimate per gross ton is as follows:

	Mining cost	Coal	Royalty	Total
Reynoldsville	$0.66	$0.86	$0.04	$0.90
Connellsville	0.34	0.52	0.08	0.60

Reducing this to a short-ton basis we find that Mr. d'Invilliers's estimate of total cost is:

Reynoldsville	80 cents
Connellsville	53 cents

These figures are for January, 1904. I find that for that year the average price of bituminous coal in Pennsylvania is reported at 96 cents. My arbitrary estimate for cost of 90 per cent. of the price gives us 86 cents for that year. Now, since it would seem that the Reynoldsville mine represents conditions not far from average in the Pennsylvania bituminous-coal regions, it appears that the difference between my estimate and Mr. d'Invilliers's estimate is not so great, but that it might all be covered by a difference of judgment between two men in "what is chargeable to operating account."

Pittsburgh Coal Company.—The reports of the Pittsburgh Coal Company, which operates sixty mines in the neighborhood of Pittsburgh, so situated that they must represent nearly average conditions for the Pennsylvania bituminous field, show the following: The average number of short tons mined per acre is 7000. Net profits for eight years average 13.8 cents per ton. The total cost for all capital charges is 16.2 cents per ton. If we assume that the U. S. Geological Survey figures for the value of coal at the mines will hold good for the Pittsburgh Coal Company, we get the following, per short ton:

Average price of coal for 5 years		$1.03
Cost—Capital charges	16.2 cents	
Operating charges	73.0 cents	0.892
Profit		0.138
		$1.030

Similarly the Monongahela River Consolidated Coal and Coke Company, also operating near Pittsburg, with an extraction of 8000 tons per acre, shows the following for nine years:

Assume price of coal as before		$1.03
Cost—Capital charges	17 cents	
Operating charges	74 cents	0.91
Profit		0.12
		$1.03

Capital Charges.—Without going into further tables of figures I find that in Pennsylvania the capital charges may be calculated as follows: A charge of 5 cents per ton is made arbitrarily to cover the depletion of coal lands. If the property is bonded, this 5 cents per ton is put into a sinking fund to retire the bonds.

In addition, current interest must be paid on capital or bonds. This charge will be in some proportion to the amount of unmined coal lands held for the future. Thus, if a company has a coal reserve for 100 years on its capital account, its interest charges must be greater than if its reserves are only enough for 20 years.

It appears that it requires approximately $1 per ton of annual product to equip a coal mine for operation. Thus for an output of 1,000,000 tons per year $1,000,000 will be needed for plant and equipment. The renewal or depreciation of this plant will cost 6 per cent. per year.

In summary, then, we have:

For coal in the ground	5 cents
For interest on $1 capital	5 cents
For depreciation of same capital	6 cents
Total	16 cents

It is self-evident that the operating costs will vary more than capital costs; probably about in proportion to the total. Thus, if we find at one mine total costs of 96 cents, of which 16 cents is for capital and 80 cents for operating, we would probably find that at another mine where the total cost is only 72 cents, the cost would be 60 cents for operating and 12 cents for capital. My reason for believing this is that a mine that is cheap to work must also be cheap to open.

While I am inclined to think that under present or recent conditions, the average cost of bituminous coal in Pennsylvania is 90 cents or more,

there is reason to believe that some of the most favorable mines work much cheaper.

Mr. Gary, in his recent testimony before the Ways and Means Committee on tariff revision, states that the cost of coke at the ovens, presumably at Connellsville, chiefly, was, in 1906, $1.75 per ton, on which there was 54 cents profit. This reduces the cost of coke to $1.21. If the burning of the coke costs 31 cents, we have left 90 cents for the coal, of which 1½ tons are required per ton of coke. This figures the cost of coal at the mines of the U. S. Steel Corporation down to 60 cents per ton. Presumably this includes a sufficient allowance for depreciation. If so, the cost seems remarkably low and probably represents the cost of bituminous coal under the most favorable conditions. At any rate it agrees pretty well with Mr. d'Invillier's figures for a representative Connellsville mine.

Certain other figures given by Mr. Gary about costs are of interest. He says that wages of all classes at coal and coke plants belonging to the U. S. Steel Corporation in 1908 averaged $2.39 per day. Now at coal mines labor is usually about 75 per cent. of the total expense; we may, therefore, calculate that the whole cost per man per day is about $3.20. If coal is mined for 60 cents per ton there must be an output of about 5⅓ tons for every man. In the State of Pennsylvania at large, the output is only 3.6 tons per man. If this output is obtained at a total cost of $3.20, then the cost per ton is 89 cents. This agrees with my other figures for Pennsylvania.

Let us apply this reasoning to other coal fields and see how close it brings us to my estimate of cost at 90 per cent. of the selling price.

In Michigan the wages are undoubtedly about the same as in Pennsylvania. I have estimated the cost of Michigan coal at $1.62 per ton. The output per man per day is 2.11 tons. If we divide $3.20 by this amount we get $1.52.

Again, in Wyoming I am informed that wages of coal miners average about $3.60 per day. If this is 75 per cent. of the whole cost per man, that cost is $4.80 per day. The output per man averaged in 1907, 3.42 tons; the cost per ton, therefore, should be $1.40. This is exactly my estimate by the 90-per cent. rule.

I have no information as to the average wages of coal miners in Colorado, but some light can be had on costs there from another source. The average value of coal at the mines in that State in 1907 is given at $1.40. My 90-per cent. rule gives a cost of $1.26. The Colorado Fuel and Iron Company mined that year about 4,500,000 tons of coal at a profit of $900,000, or 20 cent per ton. This profit was not altogether on mining since some of the coal was sold at a distance from the mines. Besides this the profits were diminished by certain fixed charges, of which the exact proportion belonging to the fuel department is not clear. At any

rate it seems that the net profits on coal from mining were not over 10 cents. If, then, the U. S. Geological Survey is right in its average price of coal, the actual cost must have been about $1.30.

Following are some more detailed figures on the cost of operating a self-draining slope mine, in Virginia. The figures are complete in all respects except that of depreciation. I am in doubt whether that item is fully taken care of, but having no means of forming an individual opinion, I cannot express one. The seam averages 7 ft. thick:

Cost Sheet at a Virginia Colliery

	1905–1906. Per ton	1906–1907. Per ton
Mining	$0.246	$0.251
Timbering	0.010	0.018
Ventilation	0.008	0.010
Removing refuse and deposit	0.005	0.017
Tracks	0.030	0.031
Haulage	0.067	0.102
Dumpage	0.009	0.012
Blacksmith shop	0.006	0.007
Repairs	0.009	0.008
Supplies	0.007	0.003
Salaries—Plant	0.017	0.019
Switching	0.005	0.006
Engineering	0.003	0.005
Extraordinary expenses	0.007	0.011
Adjustment stables account	0.005	
Sinking fund	0.100	0.100
Attorneys' fees and legal expenses	0.025	0.016
General expense	0.014	0.012
Salaries—General office	0.040	0.058
Interest and discount	0.073	0.068
Taxes	0.011	0.011
Insurance	0.005	0.005
	$0.702	$0.770
Summary:		
Labor	$0.382	0.423
Supplies	0.052	0.077
Sinking fund	0.100	0.100
	$0.534	$0.600
General expense	0.056	0.070
Interest, insurance, taxes, attorney's fees	0.112	0.100
	$0.702	$0.770
Tons mined	240,371	221,552

It is interesting to note the increased cost in 1907 over 1906, due to the unhealthy pre-panic business conditions.

The following table shows the estimated cost of coal mining in various

parts of the Illinois field, according to Mr. George S. Rice. The only comment I can make is that the estimates for depreciation and amortization seem rather low.

ESTIMATE OF COST OF R. OF M. COAL IN ILLINOIS, AVERAGE CONDITIONS

Yearly output	Northern Ill. longwall 150,000 tons		Middle Ill. 250,000 tons		Southern Ill. 250,000 tons	
	Labor	Sup.	Labor	Sup.	Labor	Sup.
Mining (paid to miners "pick rate")	$0.87	.....	$0.55	.....	$0.48	
Narrow work (entry driving and passing through rolls, etc.)	0.005	0.005	0.04	0.01	0.03	00.1
Care of mine (maintenance of roads, roof falls, timbering, etc.)	0.15	0.05[1]	0.07[1]	0.03[1]	0.06	0.02
Haulage	0.08	0.02	0.05	0.01	0.04	0.01
Hoisting and loading and care of mine top[2]	0.03	0.02	0.02	0.01	0.02	0.01
Steam	0.01	0.02	0.01	0.01	0.01	0.01
Mine management	0.02	0.01	0.015	0.005	0.015	0.005
	1.165	0.125	0.765	0.655	0.655	0.065
	.....	1.165	.....	0.765	.....	0.655
Total mine cost	.....	1.29	.....	0.83	.....	0.72
General costs: Depreciation and amortization	.....	0.05	.....	0.03	.....	0.02
General costs: Selling	.....	0.02	.....	0.02	.....	0.02
General costs: Gen'l management	.....	0.02	.....	0.02	.....	0.02
Grand total	.....	$1.38	.....	$0.90	.....	$0.78

[1] Chiefly timber and ties.

[2] These costs or the subdivision of care of mine top will run high unless the mine runs fairly steadily.

Coke Manufacture and Anthracite Mining.—The production of commercial anthracite is so different a problem from that of mining bituminous coal that its cost is nearly parallel to that of coke. Run-of-mine anthracite is worthless for fuel. It will not burn unless it is carefully sized. It will not burn if there is even a moderate mixture of slate or bone in it. The sizing and rejection of impurities necessitates careful crushing, sizing and washing. It is distinctly a process of concentration as well as of sizing, for the loss in the "breakers" will average fully one-third of the run-of-mine tonnage. The cost of concentrating, or operating the breakers, is from 30 to 50 cents per ton shipped—not cheap milling by any means, and no doubt mining men not acquainted with the fact will be surprised at it. The comparison may be tabulated as follows:

	Coke	Anthracite
Tons run-of-mine per ton	1½	1½
Cost of manufacture per ton	30 to 60 cents	30 to 50 cents

CONNELLSVILLE REGION PLANT OF 500 OVENS

Coal, 1½ tons, at 56 cents net ton	$0.840
Charging, leveling, drawing and labor	0.326
Salaries, supplies and depreciation	0.050
Total	$1.216

It will be noted that I deduce from Mr. Gary's evidence that the actual cost of coke in Connellsville to the steel company in 1906 was $1.21.

REYNOLDSVILLE PLANT OF 500 OVENS

Coal, 1.7 tons, at 70 cents	$1.19
Charging, leveling, drawing and labor	0.40
Salaries, supplies and depreciation	0.05
	$1.64

In neither of these cases have I used any table exactly as given by Mr. d'Invilliers. He does not give the details of his estimates for a five-year average, and I have endeavored to supply them. There seems to be some mistake in his average of Reynoldsville costs, for they do not work out in proportion as he gives them.

Another example of coke costs more in detail is from a 200-oven hand-operated plant in Virginia—in 1906:

Cost of coal, 70.2 cents per ton	1.027
Crushing	0.023
Charging	0.033
Leveling and sealing	0.028
Drawing	0.210
Loading	0.134
Switching	0.023
Salaries at plant	0.033
Tracks	0.008
Repairs	0.021
Supplies	0.012
Extraordinary expense	0.006
Insurance	0.001
Total	1.559
In summary:	
Raw material	1.027
Labor	0.459
Supplies	0.075
Total	1.561

The following year, 1907, the costs at the same plant were as follows:

Raw material	$1.227
Labor	0.524
Supplies	0.114
Total	$1.865

Anthracite Mining.—The extraction of run-of-mine anthracite is rather more expensive than that of bituminous coal, chiefly because the anthracite seams are very much more folded. It is necessary to do vastly more development work in rock, and necessary also to use more timber in supporting gangways than is the case in flat seams. Moreover, the constantly changing dip prevents the use of uniform methods throughout the mines. On the other hand, the coal often occurs in magnificent thick seams. The actual difference in cost for run-of-mine I do not estimate at more than 10 cents per ton, 92 cents for bituminous and $1.02 for anthracite (per short ton, the long ton is used at the mines).

Below will be found consecutive statements of the costs of the Philadelphia & Reading Coal and Iron Company for a period of years. These tables in the main explain themselves, but it is worth while to make the following comments: The actual cost of mining and repairs will be seen to average about $1.80 per long ton, equivalent to about $1.60 per short ton. This is for current operation only, but it includes the cost of putting the coal through the breakers, and it is a cost based on the finished product which may be calculated to be only two-thirds the run-of-mine product. Details for cost of breaking are not given, but from inquiries made in the region, it seems that 40 cents per ton is an average. Deducting this sum we get $1.20 for mining alone, and this is for mining 1½ tons of run-of-mine coal. The actual cost, then, per ton of run-of-mine to this company seems to be some 80 cents per short ton.

The capital and general charges that follow in the statements largely explain themselves. The only item to which I wish to draw special attention is that of improvements, which is regularly charged in as an operating cost. This is entirely as it should be, and the charge is doubtless based on the theory that the annual improvements to plant are sufficient to cover the renewal of equipment. The company has charged to improvements and equipments at collieries $13,092,635. This is equivalent to about $1.30 per ton on its annual output. Some companies would have charged a much larger amount to this item. The amount has not been increased in recent years in spite of the fact that since 1902 the output has increased 50 per cent. It is usual to charge off for depreciation at coal mines 6 per cent. of the capital employed in the plant and equipment. In the case of the Reading company such a sum would have been sufficient in 1902, but would fall far short of the charges made in 1908. As costs are usually calculated, therefore, it would seem that this company is writing off somewhat more for depreciation than is strictly necessary. It would be obviously logical for the company to hold on its balance sheet a greater capital for an output of 10,000,000 tons per year than for an output of only 7,000,000 tons.

In other words, I wish to express my conviction that the costs given by the Philadelphia & Reading company for anthracite mining are ade-

quate in all respects, and that, therefore, the accompanying statement gives an excellent idea of the real cost of anthracite mining.

The following is an interesting chart by Mr. H. M. Chance, showing the relation of cost of anthracite mining to the thickness of the seam. Mr. Chance points out that the most important factor in the variation of coal-mining cost is the thickness of the seam, and nothing will show the facts in the case more plainly than the chart which I take from Mr. Chance's communication to the *Engineering and Mining Journal* of July 29, 1909.

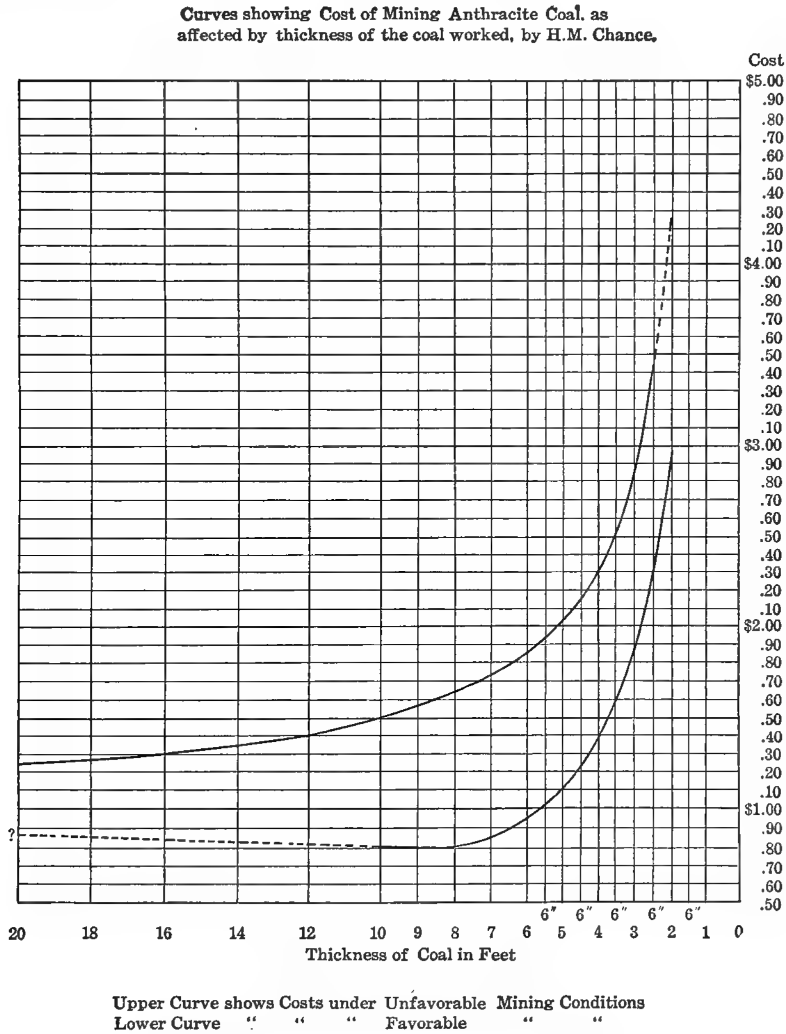


FIG. 2.

PHILADELPHIA & READING COAL AND IRON COMPANY—STATEMENT OF COSTS

	1902	1903	1904	1905	1906	1907	Per ton	1908	Per ton
Anthracite mined, tons	6,968,566	6,299,449	8,707,508	9,438,665	9,132,353	10,034,713		10,218,392	
Mining and repairs, 1.733	$12,076,964	$11,635,094	$16,683,568	$17,378,181	$16,904,915	$18,741,729	$1.867	$19,026,334	$1.865
Royalty	392,646	370,226	561,603	621,530	620,217	677,143		667,722	0.066
Taxes	253,212	255,714	239,927	305,900	296,953	296,953		339,087	0.033
Repairs of houses	17,644	15,274	22,087	57,693	37,215	53,040		49,849	0.008
Damages account dirt	35,990	6,366	47,104	25,352	7,260	15,768	0.300	2,054	
Improvements	963,428	867,330	1,273,035	1,730,974	1,131,038	1,345,229		1,286,010	0.128
Depletion of lands	374,101	340,445	454,241	478,326	458,541	499,059		514,350	0.051
Fixed charges 0.34	419,858	377,747	317,224	104,035	118,466	115,074		117,248	0.012
	$14,433,843	$13,858,196	$19,598,789	$20,691,691	$19,583,552	$21,744,995		$22,002,654	
Total cost per ton, 2240 pounds	$2.07	$2.20	$2.25	$2.19	$2.36	$2.167		$2.153	
Cost per short ton	1.85	1.96	2.00	1.95	2.10	1.93		1.93	

Public Policy in Coal Mining.—It has often been pointed out that coal in the earth is a natural resource, the use of which is important not only to the owners of the coal lands, but to the nation at large, and that since the supply of coal is limited by nature, wisdom demands that it should be wisely handled. This is a fact that has been recognized by many governments from the earliest times, and the policy of treating mining rights as public rather than as private property has been adopted by probably the greater number of nations. These ideas have been so widely discussed that they are already known to the majority of people, and I wish to call attention only to some considerations that may have a practical value.

Causes of Waste in Coal Mining.—An interesting paper[1] contributed by Mr. George S. Rice to the Transactions of the American Institute of Mining Engineers at the Chattanooga meeting, October, 1908, calls attention to the fact that the percentage of yield in Illinois from the coal seams is only from 50 per cent. to 95 per cent., and that the losses are from 5 per cent. to 50 per cent. of the available coal. It would be interesting if space permitted to quote Mr. Rice's article in full, but since that is not feasible I shall call attention to some of the principal conclusions developed.

Mr Rice summarizes the causes of mining waste as follows:

(1) Cheapness of coal "in place;" that is, in the seam.

(2) Low market prices resulting from extreme competition.

(3) Character of the seam, roof, and floor as determining the method of mining.

(4) Surface subsidence due to mining.

(5) Interlaced boundary ownerships.

(6) Carelessness in mining operations.

Mr. Rice says: "The first two factors taken together are the controlling ones in most mining operations, in influencing the choice of a mining system."

This statement is so true that too much emphasis cannot be laid upon it. It has been pointed out in Chapter II that economy may demand the sacrifice of considerable portions of low-priced mineral products in order to secure a sufficiently low mining cost; and it will be pointed out in various places in succeeding chapters that the value of the material mined is always one of the greatest factors in the cost of mining. So pre-eminent is this factor that it is almost possible to say that it is the only one of real consequence in determining percentage of waste; for it is self-evident that were the product sufficiently valuable, a system or method would be found to prevent the loss of it. The prevention of losses, therefore, as a matter of public policy, is simply a question of dollars and cents. If the public wishes the coal to be mined

[1] Mining Wastes and Mining Costs in Illinois.

cleaner, it must be willing to pay a sufficient price to make clean mining profitable to the operator.

It is also self-evident that common sense must be invoked to place a limit on efforts to secure this kind of economy. A reference to Mr. Chance's chart discloses at a glance that, as the thickness of the coal seam diminishes, the cost increases without limit—in mathematical language, approaches infinity. It is preposterous, therefore, to attempt to save all coal, because a seam one inch thick would cost $50 a ton; a seam two inches thick would cost $25 a ton; in each case at the mine. Such costs would preclude the possibility of using coal for anything like the ordinary purposes. Efforts toward the prevention of waste, therefore, must be confined strictly within limits that can easily be agreed upon as reasonable for any given district. For instance, in Illinois it might be agreed that coal seams down to a thickness of two feet should be worked. Such a decision might have far-reaching consequences in the conduct of the coal-mining business. For instance, suppose an operator had one seam 6 ft. thick and another seam 2 ft. thick. If we imagine that (1) a price is fixed that would allow the mining of a 2-ft. seam without loss and at the same time without profit, and (2) that the law requires the operator to mine his 2-ft. seam or else lose the right to mine the 6-ft. seam, it is evident that the operator would be willing to mine the coal according to all requirements; because the 6-ft. seam would be so profitable that the mining of the 2-ft. seam without profit would not be a serious inconvenience. If, however, it were a question of mining a 2-ft. seam without profit, in connection with a 3-ft. seam with a very small profit, the operator would probably feel that the returns of the enterprise would be too small and he would not undertake it.

The question of effective economy in coal mining as regards waste, therefore, is a question precisely like the productive tariff so far as its effect on the public at large is concerned. In the case of the tariff, however, the public is found to subject itself readily to loss because it is quite possible to make the majority of the voters beneficiaries of the tariff. If this is not actually the case a majority think themselves benefited, believing that it is of more consequence to them to get a higher price for the products they have to sell than to pay a higher price for the products they have to buy.

In the case of a proposal to raise the price of coal in order to prevent waste, it is not at all evident how the public could be imposed upon by such considerations. Granted that the coal miners would find such a policy an unqualified benefit, it is not clear how the public at large could be induced to pay a higher price for one of its chief necessities for no object except an altruistic regard for future generations.

It seems as if the only rational way to prevent wastes and at the

same time to secure better operation all around, with a saving of human life as well as of coal, is to permit a carefully guarded monopoly in each field of the business of coal mining. Monopoly is a disagreeable word, but it is the only one that conveys the meaning in plain English. It would have to take the form either of a consolidation of ownership or of a pooling of interests under government supervision. My own conviction is that the interests both of the public at large and of the coal-mining business itself demand such an arrangement.

The business in the United States is suffering wofully from over-competition. A vast amount of capital is invested in coal mines that is put in extreme jeopardy through the failure to secure a reasonable price.

It is just as disastrous from an economic standpoint for the coal business to be over-developed as to be under-developed. The under-development of coal mines means, of course, high prices through failure of the supply and consequent loss to the public. Over-development, on the other hand, means a loss, through a part of the public's money being tied up in useless enterprises.

It does not seem unreasonable to hope that in each mining district the government might fix a price for the sale of coal, simply on the basis of an actual cost of mining down to a certain thickness. Such a regulation of the coal-mining business would not be inherently different from the regulation of freight rates by the Interstate Commerce Commission. If such an arrangement were made all that the government or state inspectors would need to do would be to look out for the clean mining of the thinnest seams; the thick ones would be well taken care of without urging.

New Capital Required in Coal Mining Operations.—A glance at the figures in Chapter VI reveals the fact that in the ten years between 1897 and 1907 the production of coal rose from 200 million tons to 480 millions, equal to an average increase of 28 million tons a year. Without going into details we may assume that the equipment of the mines for this production must cost, on an average, at least $1.25 per annual ton. Under the most favorable conditions the cost of equipment and development is $1 per annual ton for flat bituminous coal seams; for the more difficult forms of mining, such as anthracite, the cost per annual ton is at least $2.50, and for coke production as much or more. The average amount of new capital going into the coal business, therefore, is at least $35,000,000 a year and $40,000,000 is a more probable figure. This is an exceedingly important fact to bear in mind in considering any possible consolidations in this business.

Changes in Recent Years.—The following extract is from a press bulletin of the United States Geological Survey on the Coal Industry in 1917.

THE COAL INDUSTRY IN 1917

The inventory of the nation's resources that the war made necessary brought to light many new facts about coal mining which will be of lasting value to the industry and to the public. As long as the war lasted these incidental lessons were lost sight of under the pressure of meeting the emergency created by the shortage of fuels, but with the return of peace the experience gained during the war is being gathered together in a series of reports on the industry, the first of which, "Coal in 1917," by C. E. Lesher, has just been published by the United States Geological Survey, Department of the Interior.

The period from 1914 through 1917 and 1918 and into 1919 may be regarded as a distinct epoch in the coal industry, of which the year 1917 represented only one section, but a section which, if not the most remarkable for its achievements, was at once the most chaotic and the most momentous in the history of the industry.

It is not difficult to marshal the events and factors that mark 1917 as unusual: An extraordinary demand, increasing after April, when this country entered the war, and unsatisfied throughout the year; high prices and speculation in "free" coal; the first effort at regulation of prices through the Committee on Coal Production; the Pomerene amendment to the Lever Act and the fixing of prices and appointment of the Fuel Administrator by the President; labor troubles; priority orders; car shortage and other difficulties in transportation; severe storms in December that blocked the railroads; the withdrawal of ships from the coastwise trade to New England; unequal distribution of coal and constant fear of a fuel famine in many sections; reluctance of many producers and distributors of coal to accept governmental regulations in general and the program of the Fuel Administration as it was developed in particular.

In response to the unprecedented demand the bituminous mines produced 551,790,563 net tons, or nearly 10 per cent. more than the output of the year before. The anthracite output was 96,611,811 net tons, an increase over 1916 of 13.7 per cent. The total output of both hard and soft coal was thus over 650,000,000 tons.

This record output was accomplished by a labor force of 603,143 men in the bituminous and 154,174 in the anthracite mines. In spite of the draft the number of workers in the bituminous industry was greater in 1917 than in 1916.

Material progress was made during the year in the introduction of the eight-hour day. Whereas in 1916 about 41 per cent. of the bituminous workers were employed in mines where the standard working day was longer than eight hours, in 1917 the number in such mines had fallen to 21 per cent. The change was largely the result of reduction in working hours in Kentucky, Maryland, Pennsylvania (bituminous), Tennessee, Virginia, and West Virginia, particularly in the larger nonunion fields.

In response to numerous inquiries statistics were collected regarding the thickness of vein which it is profitable to mine. Many people will be surprised to learn that in 1917 more than 20,000,000 tons of soft coal was mined from beds less than 3 feet thick. The percentages drawn from each thickness of seam are shown in the following table:

PERCENTAGE OF TOTAL OUTPUT OF BITUMINOUS COAL AND LIGNITE PRODUCED FROM BEDS OF DIFFERENT THICKNESS IN 1917

Under 2 feet	0.6
2 to 3 feet	3.2
3 to 4 feet	13.3
4 to 5 feet	17.6
5 to 6 feet	19.9
6 to 7 feet	13.8
7 to 8 feet	9.9
8 to 9 feet	5.3
9 to 10 feet	5.6
10 to 20 feet	2.0
20 feet or more	0.3
Thickness not reported	8.5
	100.00

The gradual and finally rapid change in the cost of producing coal since 1908 are shown by the records of a company producing from 4,000,000 to 6,000,000 tons a year in West Virginia.

	Mining	General	Taxes	Depreciation	Selling price	Total cost
1903	....	....	....	....	....	0.67
1909	0.60	0.09	0.01	0.02	0.85	0.72
1910	0.62	0.07	0.01	0.02	0.88	0.72
1911	0.69	0.10	0.01	0.02	0.84	0.82
1912	0.68	0.10	0.01	0.02	0.88	0.82
1913	0.69	0.11	0.01	0.02	0.93	0.83
1914	0.66	0.12	0.01	0.02	0.96	0.81
1915	0.60	0.11	0.02	0.02	0.93	0.75
1916	0.70	0.13	0.02	0.02	1.14	0.87
1917	1.04	0.18	0.04	0.02	2.16	1.28

In 1918 and 1919 it is probable that these costs rose to about $1.70 or $1.80 per ton.

In the midst of the vast amount of statistics published by the government on coal production I have not thought it worth while to enter into any further analysis. It may be stated confidently that the same forces have operated almost equally in all fields and in all departments of the business, for example in anthracite mining and in coke manufacture.

CHAPTER VIII

THE INDUSTRIAL CLEARING HOUSES AND STATISTICS OF IRON PRODUCTION

LIMITED AREAS OF IRON MANUFACTURE—THEIR ECONOMIC HEGEMONY—ITS RECENCY—REASONS FOR THE RESTRICTIONS OF IRON MANUFACTURE TO AREAS OF CONVENIENT DISTRIBUTION—POLITICAL IMPLICATIONS—PROBABLE PERMANENCY OF THE INDUSTRIAL CLEARING HOUSE AREAS—THE SUPPLIES OF COAL AND IRON OF THE PRINCIPAL NATIONS—WORLD PRODUCTION OF PIG IRON AND STEEL—PERSPECTIVE OF DEVELOPMENTS SINCE 1850.

Nine tenths of the world's output of iron is persistently made in two limited areas. If we construct a triangle the points of which are at Boston, Milwaukee and Birmingham, Ala., we shall include an area of some 275,000 square miles, within which practically all the iron of the Western Hemisphere is produced. To get the proportion of things let us remember that the area of this hemisphere exceeds 15,000,000 square miles. In Europe, if we take the island of Great Britain south of Glasgow and a territory on the continent roughly inside a line drawn through Havre to Paris to Strasburg to Vienna to Warsaw to Stettin to Hamburg, we find an area of about 325,000 square miles, within which is manufactured more than eighty per cent. of the iron of the Eastern Hemisphere, the area of which is more than 35,000,000 square miles. In these two fields there is a population of about 175,000,000 at least a tenth of all the people of the world in about one ninetieth of the land surface. Within these two tracts are found the six largest cities, the chief universities, libraries, works of art; the radiating points of literature, fashion, opinion; the seats of political, social, military and naval power; likewise the seats of finance, of manufacture and of industrial organization.

In the raising of the U. S. Liberty Loans, the area mentioned, with forty per cent. of the population of the country, was allotted seventy per cent. of the subscription. The arithmetic of this is that each person within this area was expected to subscribe two and a half times as much as a person outside of it. The same proportion of things holds true in Europe, perhaps still more strikingly. I take it that, in the United States, at least, these facts do not indicate that the average man in the indicated area is much richer or lives more comfortably than the man outside of it, still less that he is a person of superior gifts and energy; rather that for powerful economic reasons, a preponderance of the financial interests owned outside are lodged in and managed from within it.

It seems appropriate to call these areas the industrial clearing houses. It is these regions that buy the surplus foods from the rest of the world, hundreds of millions of bushels of wheat, hundreds of millions of pounds of meat, sugar, coffee and tobacco, and establish the price for them. Likewise wool, cotton, diamonds, gold, copper, tin, lead, zinc, practically all the staples of commerce, except such as may be utilized by the local handicraftsman, go to these regions for manufacture, distribution and market.

This state of affairs is of recent growth. The recorded history of great civilized communities, many of whom were more skilful in certain arts than the people of the present day, goes back at least 4000 years. Go back one tenth of that space, 400 years, and what do we find? Constantinople was then more influential than London, Rome than Berlin, Madrid than Paris. Mexico and Cuzco were seats of empire and organization, while New York was a leafy island and Chicago a swamp, both in a wilderness supporting only a few savages whose culture was that of the old stone age. It is true that in Europe, the English, the Flemings and the Germans had long been known and had made themselves felt; they had made some progress in the arts and had even invented printing, but they were chiefly known to the outside world as formidable trouble makers and fighting men, rude in manners and in speech: taking their crude ideas of fashion, learning and art by imitation of the peoples of the Mediterranean.

Even much later than this, in 1685, according to Macaulay, England had a population of some five, or five and a half, million people of whom nearly one tenth were in London. That metropolis had a death rate similar to that of Ashanti. It had no sanitary appliances or regulations whatever. Its streets were ill paved, or not at all. Gentlemen wore swords and pistols in the streets with which to defend themselves. Ladies going out at night were carried in litters, accompanied by troops of armed guards and by servants carrying lanterns. An enterprising citizen had just begun to light the streets by hanging oil lamps at a few places. Outside of London there was not a town of 30,000, and the two largest were Norwich and Bristol. Of the latter place travelers mentioned with astonishment that one could stand in the middle of the town and see nothing but houses. Liverpool, Manchester and Glasgow were villages of some three of four thousand each. The entire shipping of the kingdom measured some 70,000 tons, of which Liverpool owned one or two per cent. The roads were of the crudest sort. Coaches of noblemen and ambassadors were frequently stuck in the mud within a few miles of London, though drawn by six horses and often pushed by a crowd of servants or retainers that rode with them. Ordinary long distance travel was by horseback. The wages of agricultural laborers was from 4 to 6 shillings a week; of artizans in factories a shilling a day. The price of wheat was

about the same as it is today (or as it was before the war); the common people rarely ate it, but lived mainly on oats and barley. Macaulay, writing in 1850, reviewed with satisfaction and amazement the progress that had been made and thought it not unreasonable to suppose that by a continuance of it some future generation would see carpenters earning 10 shillings a day.

Thus England, only two hundred years ago or so, was in precisely the same economic state as the remoter parts of Russia are in now; where railroads and even turnpikes are unknown, where grain is cut with the sickle, where reading and writing belong only to the favored few. But just as rural Russia in the nineteenth century was able to produce its Tolstoi and its Verestchagin, so rural England in the seventeenth had its Isaac Newton and its John Milton. A certain nobleman, the Earl of Worcester I believe, considered a bit crazy by his friends, persisted in experimenting with a "fire," or steam engine, from which he predicted wonders. Coal was brought by ship from Newcastle to London where it was extensively used for household purposes, and because it came by sea it was called "sea coals."

It was precisely in these latter facts that lay the germs of the future wealth and power of the Anglo-Saxon race. To the accustomed pursuits of agriculture and small trade the inquiring minds of England were beginning to add some knowledge of physical science and her artizans were beginning to burn coal in their forges and furnaces.

Americans have always been in the habit of calling their country "new;" England is the "old" country. They do not realize fully that the comforts and establishments that distinguish modern life from that of former times are new in all countries, that England only preceded the United States by a few years in most of the pursuits and accomplishments which we have wished to import and imitate; and that in fact many of the conspicuous changes in modern life have originated in America as much as in Europe. It has been the habit to suppose that certain industries are peculiar to "old" countries and that the reason why such industries are not found in "new" countries is simply that those regions have not grown up. Thus I suppose many people imagine that iron manufacture may successfully be practiced anywhere as soon as people "get around to it."

But this does not seem to be the case. It is true that iron manufacture on a large scale has migrated from England eastward into Germany and westward into the United States. It is true also that it will probably flourish in other regions in the course of time. A considerable beginning has been made in southern Russia, and a still greater industry may spring up in China, some day. But one essential fact must not be overlooked; this industry has only migrated as far as, and to those regions in which, the conditions in the British Isles are duplicated or improved upon.

The reasons which anchor the industry within such limits are strong ones and lie in a combination of natural, commercial and financial circumstances that are not easily or quickly altered. We concede that human affairs are mutable and that the splendors of today are merely the ruins of tomorrow and still we shall find reason to believe that the present general relations of the industrial world are pretty firmly established; quite firmly enough to form the true basis for the political thought of the present age.

It is scarcely worth while to dwell upon such commonplaces as that iron is the most abundant and most useful metal used by man, that its manufacture requires large supplies of fuel, ore and labor. Other factors are equally important and upon moderate consideration, equally obvious.

1. The heat, power and labor that will make iron effectively may be applied with equal effectiveness to other manufactures. It follows that wherever these supplies are such that iron can be manufactured cheaply, other commodities may likewise be manufactured cheaply.

2. Iron goes into a multiplicity of uses and a multiplicity of forms, each requiring special appliances and even a special plant for its production. Thus the industry is tremendously specialized. For instance a factory in Pittsburg employs 2500 men just making bolts and nuts. Such manufactures can only flourish in centers from which great consuming populations may be supplied. To illustrate this point let us imagine the establishment of an iron industry on the Pacific Coast, say at San Francisco, to supply iron to the state of California. Let us imagine that adequate supplies of ore and fuel are to be had, which is not of course the case. The people of California might consume about 1,000,000 tons of iron a year, but in what forms? Why in all forms. They would need steel rails, structural forms, castings of all descriptions, tools, machines, nails, barbed wire, galvanized iron, bolts and nuts, and many other kinds of iron each of which requires a special plant. Each product would have to be supplied in about one fortieth as great a quantity as that in which it is made in the eastern district. Now the initial cost of a plant contains a certain constant expenditure whether the plant be small or great. There must be a site, buildings, power plant, machinery and facilities for transportation. It is only after this foundation is laid that the appliances for producing the specialty may be added at a cost which will be in a fixed ratio to the product. Is it not evident that to build a complete iron industry in California will require much more capital per ton of product than will be required in Pennsylvania? The actual cost of plant per ton produced annually in some departments of this business must run up to $200 to $500. The use of such capital and the depreciation of such a plant would be, say, 10 per cent, equal to $20 to $50 a ton. If it should cost twice as much capital to start a similar plant in California, where one fortieth as much product could be marketed, such a plant

would have to stand additional overhead charges of $20 to $50 a ton. Such sums are more than enough to pay the cost of transportation to almost any place in the civilized world. The figures are imaginary but they are within reason and illustrate the principle.

3. The facilities for manufacture are not the only advantages possessed by the chief industrial areas. They are also above the average in natural agricultural and trading resources. The manufactures support a population that is merely superimposed upon populations that would be there anyway. This adds to the marketing facilities and becomes a factor in building up trade from the mere effect of momentum. The widest opportunities for business lie where the greatest number of people to do business with may be found. The ambitious, the enterprising and the able flock to the great industrial centers to try their fortunes; and bring with them capital and organizing power that grow into imposing volume. In such centers, hundreds of specialized employments are found which scarcely are known elsewhere. Indeed the greatest cities are largely made up of them. New York, for instance, is not supported by any great industry so much as by the specialists of all industries.

People often wonder why cotton grown in the South is not manufactured in the South. The explanation is very simple. Our Southern States produce enough cotton to supply twenty times the population of those states. Nineteen twentieths must therefore be exported. The baled cotton is scarcely more bulky and can be handled more easily than the manufactured cotton. It all has to go to the distributing centers for market: if, in so doing, the cotton reaches localities where it can be manufactured more cheaply, advantageously and skilfully than at home, that is the natural place for its manufacture. That is precisely what happens. Within a hundred miles of New York nearly as many people live as in all the cotton growing states—a population infinitely richer in skilled and specialized artizans, with infinitely superior commercial advantages. Exactly the same thing is true of other staples; metals for instance. Why try to manufacture copper in Arizona when it has to go to New York or Europe anyway? Copper is used in conjunction with iron for the general manufacture of machinery appliances and structures. Eighty-three pounds of iron are used for each pound of copper. Does not this fact chain the copper market to the iron producing locality? We may go through a long list of other such staples and find that the same circumstances apply to them all.

It now becomes clear why so much more money is to be found within these clearing house areas than outside. The commercial, industrial and financial transactions—the market—of most of the staples from the outside, as well as of those originating inside, are conducted in these centers. It is these transactions that involve the principal use of money.

The performance of all this business in the industrial clearing houses is not an exaction upon the rest of the world—as some frequent ranters beset with half information urge us to believe—but a service. It is a plain matter of mutual advantage.

I have hinted at a political implication; we have now arrived at it. The service performed by these clearing house areas depends upon the free access to and free interchange with all of the outside world. Artificial barriers, such as national antagonisms, which interfere with it, are a handicap and a hardship both upon those within and upon those without. But the people without are not so vitally affected as those within. The industrial areas are over-populated. A stoppage of their trade means starvation and disaster in the acutest form. A mere strike on the transportation systems leading to New York would bring that metropolis to discomfort in a week and to black calamity in a month. It is the province of true political organization and adjustment to recognize this fact. In America the clearing house area is securely backed by the political structure of a great continent. Its intercourse with an immense feeding and trading area is as well assured as human institutions can make it. The United States is big enough to command it. But it is the misfortune of Europe that the fortunes of the great industrial nations may be at any time endangered by the jealousy of rivals. The exploitation of such jealousies is the most formidable cause of war. The actual fighting in such a war produces only a small part of the suffering involved in it; the major part lies in the economic distress thrust upon hundreds of millions. It remains to add that the interests of the industrial areas are the interests of *Capitals.* They are the industrial, social, financial capitals of the world, made so by the inevitable and proper working out of economic forces. They should be accorded the political privileges of capitals also: and just as their position as commercial capitals rests upon mutual advantage, so should their position as political capitals rest upon mutual advantage.

How firmly is this state of affairs rooted in natural conditions? In other words, how permanent is it?

Allocation of Iron and Coal

The International Geological Congress meeting in Stockholm, Sweden in 1910 made a survey of the iron ore resources of the world and in Montreal, Canada, 1913, a similar survey of the coal resources of the world. It must be admitted that neither of these reports can pretend to great accuracy (1) because many fields of both coal and iron are only slightly developed and therefore the tonnage estimates are largely conjectural, (2) because the elements of known fact and conjecture are not reported in the same way for the different fields and (3) because the commercial

factors which in every case put some limit upon the exploitation of resources are very imperfectly considered. But in spite of these limitations certain broad features of the world wide situation stand out clearly enough as follows:

Coal

1. The resources in both coal and iron are distributed very unequally among the nations and races. Thus the Latin speaking nations both in Europe, America and Africa have very inferior supplies of coal both in quantity and quality.

2. The territories occupied wholly or almost wholly by English-speaking white populations, amounting in all to less than one-tenth of the human race include not less than three quarters of the probable coal supplies. The preponderance of the remaining supply is in China.

3. On the continent of Europe, that is, excluding the British Isles, 71 per cent of the probable resources are in the former German Empire.

4. Disregarding the hazy and uncertain estimates of probable and possible coal supplies and considering only those portions that are put down as "actual reserve," the great coal producing nations are undoubtedly well equipped for the future. Thus Great Britain has enough coal in actual reserve to maintain its present output for approximately 500 years, Germany for 400 years and the United States, though its resources are not estimated in the same way, is undoubtedly much better off still. Thus in regions where coal is of the best quality and demonstrated to be of present commercial importance, the output can certainly be maintained and increased for a period of at least 100 years, that is, well beyond the limits of reasonable human foresight.

5. On the other hand France has only enough coal in "actual reserve" to maintain her comparatively modest output for 90 years, Italy has no supplies worth mentioning; Russia though credited with large potential supplies, has very little in actual reserve; Japan has only enough to maintain its present small output for 90 years, and India with its immense population has only enough for 30 years.

Iron

In iron the situation is as follows: The three greatest sources of high-grade ore, that is, carrying 50 to 66 per cent. metallic iron, are the Lake Superior region in the United States, northern Sweden and south-central Brazil. Immense supplies, measured by billions of tons of low grade ore running 25 to 40 per cent. metallic iron are found in Great Britain, France and Germany near great fields of good metallurgical coal. Numerous other occurrence of fair and good-grade iron ores occur in other

parts of the world, as in Spain, Newfoundland, Cuba, Chili, Mexico, Venezuela, India, China, Australia and Russia, but these supplies are not great enough, rich enough or in situations favorable enough to give them at present commanding commercial or political importance.

The following situations seem well established:

1. The United States has enough high-grade iron ore to guarantee its present maximum production of 40,000,000 tons of iron a year for about 60 years, and if we may include the resources of Cuba as falling into her field she has enough for at least 80 years. Of lower-grade ores there is an indefinite supply. By high-grade we must understand ores yielding at least 50 per cent. metallic iron on the average. In the Lake Superior district there is at least 2,000,000 tons of such ore perfectly developed and forming the back bone of the industry. These ores are situated at an average distance of about 900 miles from the greatest fields of metallurgical coal in the world, but connected with them by a singularly easy transportation route through the Great Lakes. This makes the natural meeting point of ore and fuel coincide with the center of population, and of natural trade distribution of the North American continent, and gives the industry based on these factors an unrivalled strategic position for controlling the greatest market of the world. This had led to iron being manufactured by larger productive units and no doubt under conditions which yield a greater output per man than is possible in any

Actual Iron Ore Reserves of Principal Iron Manufacturing Countries

	Ore, tons	Metallic iron	Per cent.
France	3,300,000,000	1,140,000,000	37, Self flux.
Spain	711,000,000	349,000,000	50
Austria	250,000,000	90.000,000	36
Hungary	33,000,000	13,000,000	40
Russia in Europe	864,000,000	387,000,000	44 Europe, 40%
Sweden	1,158,000,000	740,000,000	65 100 years sup-
Great Brigain	1,300,000,000	455,000,000	35 ply.
Germany	3,607,000,000	1,270,000,000	35 Self flux.
Total	11,223,000,000	4,444,000,000	
United States	4,257,000,000	2,300, 000,000	53%
Newfoundland	3,635,000,000	1,961,000,000	For export only.
Cuba	1,903,000,000	856,000,000	For export only.
Brazil	5,000,000,000	3,000,000,000	60 %
Australia	135,000,000	73,000,000	Practically unexplored.
British Isles	100,000,000	65,000,000	
Chna	100,000,000	60,000,000	
Japan	44,000,000	28,000,000	

other field. Under these conditions the United States should be able to command a considerable exportation of iron to countries in which iron manufacture is either imperfectly developed or not feasible.

2. Germany or at least the territory in which German is spoken has supplies of ore averaging only about 35 per cent. in metallic iron, but having the three great advantages (1) of being mainly self fluxing, (2) of having a favorable texture for both cheap mining and cheap smelting and (3) of being close to great fields of metallurgical coal. Of these ores she had within her previous borders enough to maintain her maximum output of 20,000,000 tons a year for 60 years. If we may credit the Germans with ability to import half the Swedish supply, half the French supply (which is an immediate continuation of her own principal field) and one quarter of the Spanish supply, it is easy to see how she can maintain her output under conditions approximately as favorable as the present for 100 years to come. Since this manufacture is near the center of European population, from which radiate favorable transportation routes both by land and water, the Germans seems well equipped to dominate the markets of central Europe indefinitely. It would seem as if these factors gave them the second position both as to natural conditions and as to markets.

3. Great Britain held the leadership of the iron trade until about 1890, but since that time she has been outstripped first by the United States and then by Germany. It is thought that she has been slow to adopt modern intensive methods of manufacture, but it is probable that her decline is based rather on the fact that her home market is less extensive than those of her chief competitors. In the export trade she is still a formidable competitor for any rival. Her natural factors seem to be rather superior to those of Germany in coal and rather inferior in iron and her access to over sea markets is more secure than that of Germany, even in peace times. Her indigenous ores are estimated to guarantee her present output of about 10,000,000 tons a year for 45 years and if she can import half of the Spanish supply, one quarter of the Swedish supply and a fair amount from Newfoundland, it is easy to see how Great Britain also can maintain her present output under conditions practically as favorable as the present, for 100 years.

From these brief analyses I take it to be a fair conclusion that the three great industrial nations are well equipped, so far as the basic raw materials, coal and iron, are concerned, to maintain their present lines of development well into the immediate future. It remains to analyse the situation of other nations to see how far they are likely to challenge the industrial position of the present leaders. For a probable source of such a challenge it is natural to turn first to Russia.

This great country possessed in a solid block one-sixth of the land surface of the world and one-tenth the population. While that popula-

tion is probably less homogeneous than that of the United States, we may assume that it is much more homogeneous than several other great empires. When we come to its resources we find that it is more nearly analogous to Canada than to the United States. At least one-half of its area is north of a line beginning at a latitude of 60° North at the western frontier and ending at 50° North at the Pacific. This area is no more capable of maintaining dense population than that part of Canada which lies north of a line beginning at Skagway, Alaska and ends in Labrador. Another large part of its area is the desert, or semi-desert lying east of the Caspian. Thus from the standpoint of habitability Russia is a long monotonous strip of plain, widest at its extreme west and gradually narrowing between the encroachments of an arctic climate on the north and mountains and deserts at the south, until before Asia is crossed it comes to an end. Outside of these limits Russia presents various conditions varying from those of our Nevada deserts to those of Cockburn land. Thus in agricultural land and possibly in forests Russia is about twice as big as Canada; but in commercial routes, and in those resources which promote industrial activity it is relatively inferior.

According to the investigations of the International Geological Congress Russia both in Asia and Europe has scarcely one-sixth as much coal, and if we may include Newfoundland with Canada, less iron. Though her iron-ore reserves are ample to maintain her present output for 100 years, she is relatively no better off than the present industrial leaders. The known ore reserves average about 44 per cent. metallic iron. These conditions do not indicate that Russia is in a position to bring about any revolutionary change in the industrial world. Her production of coal and iron as compared with other countries has not been improving very fast. Thus in 1850 Russia with an output of 230,000 metric tons of pig iron was the sixth in the list of producers, in 1913 the last year in which figures are available undisturbed by the war, with 548,000 metric tons, she was fifth. In 1850 the United States producing 573,000 tons was second on the list; in 1913, with 31,482,406 tons she was first. In 1850 Germany produced 354,000 tons and was fourth; in 1913 she produced 19,292,000 and was second. Thus while Russia has increased her production 20 fold, the United States and Germany have each increased theirs 55 fold. From 1900 to the outbreak of the war Russia had increased her output more than 55 per cent., the United States and Germany each 126 per cent., France 95 per cent., Canada 1074 per cent., Belgium 144 per cent., and Great Britain has remained practically stationary. These figures represent Russia's industrial progress, I should imagine, as well as any others; for modern industry means the use of machinery and the manufacture of iron the manufacture of machinery. That a country with such resources is able to do more than it has in the past may be taken for granted but

how much more is questionable, particularly in view of the present and prospective political and industrial unrest, and the disintegration of the country into smaller units. And when we consider how long a road she must travel to equal even the present industrial activity of the great western nations, one is tempted to doubt if we are warranted in expecting it. I feel almost convinced that Russia will never be able to match either of the three great leaders, and certainly not the United States.

In Japan we find an energetic and intelligent people living upon an already over-populated group of islands and exceedingly ambitious to join in competition with the industrial nations of Europe and America. So far as reserves of coal and iron are concerned we see from the tables given herewith that she is hopelessly inferior to any of the big competitors just discussed. However, in Korea, Manchuria and China she may find the raw materials for industrial expansion. Whether she can so utilize the enormous coal resources of China and the probably great iron resources of eastern Asia that she can build up an industrial system to match those of Europe and America (no doubt a possibility from the standpoint of natural and human material, and routes for assemblage and distribution with reference to a great population which might one day afford a great market) is an enormous problem of politics as well as of economics. It will be a fascinating and exceedingly difficult task and well worth the effort for only by success in this direction, whether under the leadership of the Japanese or of the Chinese, can we see any hope of rescuing the great yellow races from the distressing poverty which now holds their great inherent energy inertly anchored to the soil. Capital, intercommunication, education, freedom, organizing capacity and political power all spring from the same source, productive power. Once securely growing we may imagine that industrial energy in that field may acquires enormous force.

We must remember that national growth and power are not wholly measured in military terms, though I have shown that military power to be stable must be based upon industrial power. The greatest value of industrial power lies in the fact that it means prosperity. The ownership of vigorous industry is not wholly dependent upon natural resources, because human ability can overcome obstacles, but that ownership is exceedingly important. The virile nations of the present day and of the immediate future will undoubtedly scrutinize their mineral resources, among other things, with closer attention than ever.

World's Production

The world's production of iron and steel, so far as data are available, is noted in the accompanying tables:

PIG-IRON PRODUCTION OF THE WORLD
(In metric tons)

Year	Austria-Hungary	Belgium	Canada	France	Germany	Italy	Japan
1908	1,650,000	1,206,440	572,284	3,391,150	11,813,511	112,924	....
1909	1,958,786	1,632,350	686,886	3,632,105	12,917,653	207,800	....
1910	2,010,000	1,852,090	726,471	4,032,459	14,793,325	215,000	....
1911	2,095,000	2,046,280	832,376	4,426,469	15,280,527	302,931	53,065
1912	2,312,689	2,301,290	920,636	4,871,992	17,852,571	379,987	56,341
1913	2,369,864	2,484,690	1,024,424	5,311,316	19,291,920	426,775	56,663
1914	2,020,000	1,454,400	710,481	5,025,000	14,389,547	385,114	74,055
1915	1,960,000	68,150	828,920	4,750,000	11,790,199	377,510	64,984
1916	2,418,322	127,825	1,060,787	1,447,000	13,314,238	467,005	77,283
1917	....	7,990	1,063,084	1,684,000	13,142,247	471,180	....
1918	....	....*nil*...	1,084,642	1,297,000	11,754,542	313,576	....

Year	Russia	Spain	Sweden	United Kingdom	United States	All other countries	Total
1908	2,748,000	403,500	563,300	9,438,477	16,190,994	550,000	48,640,419
1909	2,871,332	389,000	443,000	9,818,916	26,108,199	550,000	61,217,064
1910	3,042,046	367,000	604,300	10,380,723	27,636,687	525,000	66,210,720
1911	3,521,000	408,667	633,800	9,718,638	34,027,940	485,000	73,831,693
1912	4,197,638	403,243	701,900	8,751,464	30,202,568	485,000	73,443,043
1913	4,548,376	424,773	735,000	10,481,917	31,482,406	495,000	79,133,124
1914	4,261,008	425,000	635,100	9,005,898	23,721,115	420,000	62,536,718
1915	3,696,560	439,835	767,600	8,793,659	30,414,817	415,000	64,367,234
1916	3,737,593	497,726	737,300	9,193,656	40,092,043	425,000	73,595,778
1917	3,000,000	357,699	821,200	9,572,190	39,243,018	....	....
1918	....	386,550	749,800	9,184,974	39,677,728	....	....

STEEL PRODUCTION OF THE WORLD
(In metric tons)

Year	Austria-Hungary	Belgium	Canada	France	Germany	Italy	Japan
1908	2,025,182	1,065,500	534,631	2,727,717	10,480,349	537,000	....
1909	1,969,538	1,370,000	684,677	3,034,571	12,049,834	661,600	....
1910	2,188,371	1,449,500	745,971	3,506,497	13,698,638	635,000	....
1911	2,363,008	2,192,630	800,504	3,680,613	15,019,333	736,000	10,222
1912	2,785,105	2,515,040	868,811	4,078,352	17,301,998	801,951	12,451
1913	2,682,619	2,466,630	1,060,503	4,686,866	18,958,819	846,085	13,728
1914	2,190,759	1,396,300	751,738	2,655,854	15,619,719	796,152	15,386
1915	2,686,226	98,820	926,157	1,087,700	13,237,646	1,009,240	16,766
1916	3,340,000	99,371	1,295,707	1,951,892	16,182,520	1,269,486	23,861
1917	2,920,000	9,530	1,583,786	2,231,651	16,587,360	1,331,641	....
1918	1,763,745	10,540	1,699,886	1,807,931	13,756,813	992,523	....

Year.	Russia.	Spain.	Sweden.	United Kingdom.	United States.	All Other Countries.	Total.
1909	3,071,000	309,479	310,600	5,976,322	24,338,302	325,000	53,499,974
1910	3,479,000	316,301	468,600	6,477,110	26,512,437	315,000	58,656,312
1911	3,870,000	322,981	456,500	6,565,645	24,054,918	315,000	60,387,354
1912	4,498,000	317,880	508,300	6,904,546	31,751,324	325,000	72,668,758
1913	4,827,000	365,118	582,700	7,787,264	31,822,555	325,000	76,157,262
1914	4,732,000	382,044	500,600	7,918,243	23,904,914	300,000	61,163,709
1915	4,900,000	387,314	588,800	8,687,670	32,686,887	300,000	66,613,226
1916	4,696,000	322,931	717,600	9,344,520	43,462,336	320,000	83,026,332
1917	3,000,000	470,241	681,700	9,909,338	45,786,083	350,000	84,894,119
1918	....	303,206	524,800	10,434,059	45,178,307		

PRODUCTION OF PIG-IRON IN PRINCIPAL COUNTRIES IN 1850, 1890, 1900, AND 1910–1912, IN LONG TONS

Country	1850	1890	1900	1910	1911	1912
United States..........	563,755	9,202,703	13,789,242	27,303,567	23,649,547	30,506,047
Germany..............	350,000	4,584,882	8,381,373	14,559,509	15,404,648	17,586,521
Great Britain..........	2,300,000	7,904,214	8,959,691	10,012,098	9,718,638	8,839,124
France................	405,653	1,931,188	2,669,966	3,974,478	4,309,498	4,870,913
Russia................	227,555	912,561	2,889,789	2,992,058	3,531,807	4,133,000
Austria-Hungary.......	250,000	910,685	1,472,695	2,153,788	2,056,839	2,276,141
Belgium..............	144,452	775,385	1,001,872	1,822,821	2,072,836	2,307,853
Canada...............	....	19,439	86,090	740,210	824,368	912,878
Sweden...............	150,000	483,155	518,263	594,385	624,367	688,757
Spain.................	....	176,598	289,315	367,423	402,209	*a*400,000
Italy..................	....	14,094	23,569	347,657	298,144	373,960
Japan.................	....	....	....	186,794	*a*200,000	*a*200,000
Other countries........	10,000	80,000	100,000	*a*250,000	*a*200,000	*a*200,000
Total..............	4,401,415	26,994,904	40,181,865	63,304,788	63,342,901	72,566,084

a Estimated. Estimate for 1913, 76,000,000 long tons.

CHAPTER IX

LAKE SUPERIOR IRON. OLD RANGES

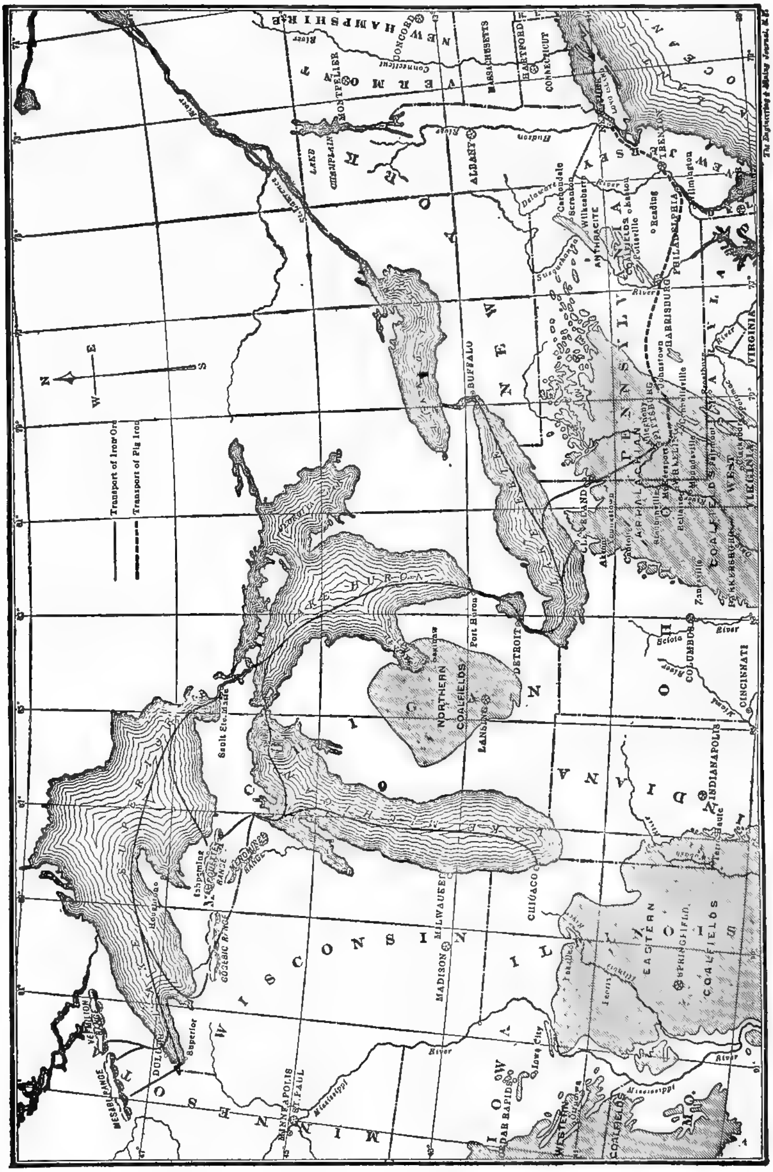
AREA OF LAKE SUPERIOR IRON REGION—THE HURONIAN OR ALGONKIAN CYCLE OF WORLD HISTORY—THE POST ALGONKIAN MOUNTAIN RANGE—DISTRIBUTION OF THE IRON FORMATION—ITS EXTRAORDINARY VOLUME—OUTPUT OF VARIOUS RANGES—ECONOMIC RESULTS IN THE MICHIGAN DISTRICTS.

Patches or "Ranges" of silicious iron bearing rock of Algonkian age are scattered over a large area, from Escanaba on Lake Michigan westward to beyond the Mississippi near Brainerd, Minnesota, 350 miles; and from Baraboo in southern Wisconsin to Gunflint Lake on the Canadian border of Minnesota, 300 miles. A line looped loosely around these points encloses an area of some 75,000 square miles, a good deal of which is occupied by the waters of Lake Superior and by small lakes.

Within this area the natural exposures of the iron formation or even of the rock formation, the Huronian series, that contains them, are small. he Huronian rocks are covered in large part by the lakes, and equally by the volcanic masses of the Keweenawan copper bearing series, also pre-Cambrian in age, by Paleozoic sediments, and by glacial drift with its accompanying bogs. They have also been worn through in many places exposing the still older Archæan cores of old anticlines. These circumstances added to the fact that these rocks are metamorphosed and contorted in violent contrast to those that occupy the surface of the adjacent regions, are a sufficient explanation of the obscurity and difficulty of the geology. The unraveling of it has been a slow process in which observers have often been unable to dissociate theories from the facts. There has been intensive study of particular districts in the effort to unravel special complexities and only an occasional attempt to describe the geology of the region as a whole. I shall try no more than to set down a few of the salient facts that are not open to controversy.

The Algonkian plainly represents, as mentioned above in the chapter on coal, a major cycle of sedimentation and quiescence, sharply marked from the preceding Archæan and the following Paleozoic by world wide crustal readjustments or "revolutions." Both in this region and in other parts of the continent the observer is soon convinced of their grand scale; perhaps there is a tendency to be over-impressed by it. Only in the Appalachian border on the east and in the Great Basin border on the west does the Paleozoic succession equal the imposing sedimentary masses of the Huronian series of the Lake Region, or the Belt series of the

west, which are no doubt more or less coeval. But I think we may safely conclude that the great thickness of the Huronian and Belt strata are due to precisely the same reason that makes the Paleozoic thick in Penn-



MAP SHOWING TRANSPORT OF LAKE SUPERIOR IRON TO SMELTING AND CONSUMING CENTERS

FIG. 3.

sylvania and the Cretaceous thick in Colorado—they are remnants of great troughs or continental borders of active sedimentation and subsidence. The deeper portions of these troughs are in general the portions

that are preserved and exposed, and to which attention has been particularly drawn; the scantier Algonkian sediments that probably were formed elsewhere having been more generally removed by erosion, and, either much less observed, or probably in many places confused by observers with later formations. The Huronian of Lake Superior is in general very much like the Paleozoic of the Appalachian trough; the resemblances preponderate greatly over the divergences. The Paleozoic does not represent a continuous deposition of sediment; it is interrupted by several unconformities or erosion intervals. The Huronian in the iron region is exactly the same; it is interrupted by two erosion intervals or moderate unconformities which affect different parts of the area very differently and change the succession of rocks from place to place. The rocks are such as are usually found in areas of persistent and active sedimentation, consisting in both cases very largely of sandstones and shales with limestones rather subordinate in volume. The Huronian is not nearly so rich in limestone as the Appalachian trough, but it contains nevertheless large masses of it.

Within the area we are considering the peculiar "iron formations" were deposited apparently exactly in the manner of normal limestones, making huge masses of strata as much as 1400 feet thick, undoubtedly in lenses the largest of which may have covered originally 10,000 or 15,000 square miles. Many attempts have been made to explain the formation of these iron bearing sediments, but none seems to be wholly convincing; suffice it to say that they were certainly formed in clear sea water as limestones form; the deposition being interrupted occasionally by invasions of mud, which in some cases represent wide-spread suspensions of the iron deposition, perhaps from failure of the supply of iron bearing material; or perhaps representing a proximate filling of the basin so that waves and currents had more power to spread silts. At any rate in each case the clear-water basins were finally filled and great shale deposits, apparently of delta mud, were formed over them; just as in many other places great masses of shale have formed over lime-stones, representing the substitution of low plains or muddy shore lines for shallow clear-water seas. Many of the Huronian shales are exceedingly carbonaceous, containing beds of graphite, so that it is not improbable that the old deltas contained peat swamps, although the vegetable forms have been obliterated by the widespread metamorphism.

The original position of the Huronian trough is largely guess-work. The present distribution of the rocks, not improbably, was determined more by the later mountain-building forces than by the original deposition. Still there is fair reason to believe that the longer axis of the trough ran approximately east and west, for numerous fragments of it occur all the way from Sioux Falls, South Dakota, to north central Quebec, thirteen hundred miles, but the greatest width indicated is only

300 miles north and south. Indeed there is nothing radical in the supposition that this trough extended westward north of the Black Hills, into Montana, Idaho, and California, on the west and to New Jersey, where there is a thick mass of Algonkian limestone, or perhaps more directly to Newfoundland, to the east. This extension at the greatest would not make it as large as the Upper Cretaceous trough which extended from the Gulf to the Arctic Ocean. At any rate it is clear that in some such area there was a broad low-lying plain never far above and never far below sea level, that was filled partly by chemical deposits in shallow sea water, but principally by shore sands and river silts washed in from one or both sides.

The peculiar chemically-deposited iron formations seem to have been either cherty iron carbonates or unstable iron silicates, in all cases containing at least 50 to 60 per cent. silica and averaging from 25 to 35 per cent. iron.

While the geography of Huronian deposition is decidedly conjectural, the succeeding "revolution" presents some points that are well established; the earth movements affected the whole world, the North American continent was elevated and suffered a period of erosion more prolonged and widespread than in any time since. However, the differences between this event and succeeding ones may easily be exaggerated; in fact it is hard to point to anything that has not been repeated or paralleled in later times. It is perfectly plain that a first class mountain building movement cut through the heart of the former trough. Very possibly the new mountain range split the old basin longitudinally as the Front Range splits the Cretaceous trough, but that point is doubtful; it may cross it at an angle. At any rate a mountain range comparable to any of the present great mountain ranges, the Alps for instance, was formed along an axis that runs some distance south of Lake Superior, almost parallel to it, in an E-W or E-N-E direction. The mountain building axis was of course not a line but a broad belt sweeping across the northern part of Wisconsin and Michigan. The edge or front of this range can be accurately located today for a considerable stretch, namely from the Huron Islands at the mouth of Keweenaw Bay, through L'Anse, Lake Gogebic, and along the Gogebic iron range to its west end, 160 miles. North of this line there is merely a basin in which the rocks are gently folded, apparently by mere subsidence; south of it there is a broad belt of intense folding, faulting and batholithic intrusions. The whole mass of Huronian sediments on the Gogebic Range is merely tilted up against the side of the uplift and thus marks its position just as plainly as the tilted Cretaceous sediments, along the Front Range mark the edge of the Rocky Mountains.

Along the mountain range itself the uplift was sufficient to bring the underlying Archæan above the level of subsequent erosion over a good

part of the range. The iron bearing rocks within the ancient mountain zone are found only in a series of synclines which in each case represented at one time a longitudinal mountain valley. These folds are very sharp, and metamorphism has been in places complete, so that now many of the sediments have become crystalline schists. The whole country, by the way, was almost base-leveled by erosion before upper Cambrian, or Ordovician, times and has remained singularly quiescent ever since.

There is nothing mysterious or unprecedented about any of these facts: for instance the Ordovician strata (which in Lake Superior are completely undisturbed) on Manhattan Island are metamorphosed into the "Hudson Schists" which every stroller sees in Central Park, and these rocks are as tightly folded, as thoroughly crystalline, as completely base-leveled, as any in Lake Superior and represent a similar mountain system. Jurassic strata, much later still, are just as thoroughly affected along the Coast Range, and the Sierra Nevada in California. Perhaps the nearest parallel afforded by later geological structures to the present Huronian of Lake Superior is the mid-Paleozoic mountain range, now pretty effectively base-leveled, that extends from New York City northward through western Connecticut, Massachusetts, and Vermont, past Lake Champlain to the neighborhood of Quebec, for a length of 500 miles, and an unknown distance south along the present Atlantic border.

The iron deposits are not peculiar to Huronian time, for some of them belong to the antecedent Archæan. Algonkian rocks in other areas are as free from iron as any others. The iron ores, therefore, belong to the region much more emphatically than to the age. There has been decidedly too strong a tendency to assume that jaspery masses containing hematite or magnetite in the pre-Cambrian regions of Canada are "Huronian." Some of them may be, but I have seen many of them in various places belonging to various ages that seem to be vein-like silicifications, and of course have not the slightest connection with the great sedimentary formation of the Algonkian. It seems worth while to emphasize that the sedimentary character of this series is not only unmistakable, but quite normal, so that every rock and every attitude in it can easily be duplicated in the formations of later times in all parts of the world. It is only the extraordinary volume of the iron that is unique.[1]

The Iron Ores.—I have ventured to give this rough sketch of the geological history of the Huronian believing that it would give a more comprehensive idea of the country in a few words than could be conveyed by a description of the various mining districts that are found in it.

[1] In the following references to Lake Superior geology, I am following the recent conclusions of R. C. Allen, until recently head of the Michigan Geological Survey. So far as I am warranted in having a personal opinion I believe this work of Dr. Allen's to be sound and his deductions essentially probable.

These districts are called "Ranges," quite appropriately in some cases, not so much so in others. All of these ranges, omitting the unimportant one at Baraboo, Wisconsin, and the Vermillion in Minnesota, which is not of Huronian age but Archæan, lie in a zone running from Escanaba, Michigan to Grand Rapids, Minnesota, 350 miles in a straight line. All the occurrences of iron formation, of any consequence are found within 50 miles north or south of this line. There is thus some suggestion that this zone may have been the locus of the peculiar iron deposition, especially in the more important middle Huronian division of it. The middle line I have mentioned passes immediately along the Menominee Range where the iron formation occurs in a number of sharply compressed folds, goes through the heart of the Crystal Falls and Iron River districts where it occurs in a lens or lenses included in folded carbonaceous slates, bisects the immense mass of the Gogebic Range, a monocline dipping under thousands of feet of overlying slate and more thousands of feet of copper bearing eruptives at an angle of 60° toward Lake Superior, and cuts into the western end of the still greater mass of the Mesabi. These ranges might therefore be called the central ranges and they produce almost 90 per cent. of the ore of the whole field. The Marquette Range, some fifty miles to the north, produces most of its ore from a large fragment of the Huronian iron formation, similar in all respects to the main formation of the other ranges, but eroded more extensively before the succeeding upper series was laid down upon it.

It occupies an E. W. syncline about six miles in maximum width running westward some forty miles from Marquette, on the shore of the lake, between boundaries of Archæan granite until it debouches into a large folded area of Upper Huronian slate. In this district the iron formation occurs principally in the patch of "Middle Huronian" in the central part of this trough; that in the upper series occurs probably as isolated or marginal lenses in carbonaceous slates toward the west end of the trough. The Cuyuna Range is only partially developed. It lies 40 or 50 miles south of the axial line and it too shows great masses of iron formation enclosed between slates and plicated in various E-N-E folds.

The Gogebic and Mesabi Ranges are by far the greatest and the simplest of all. They do not lie in compressed folds at all like the others but merely dip under the great Lake Superior trough from opposite sides—the Gogebic steeply to the north, 60° or more, the Mesabi nearly flat, say 5° to the south. Although these masses are 140 miles apart at their centers there is reason to suppose that they may be the same beds. If so the amount of iron contained in the intervening basin under the western prong of Lake Superior is simply staggering. The area of this section is some 8,000 square miles, at that only a part of the original deposit, and if it averages only 400 feet thick, this bed would contain about

8,000,000,000,000 tons, an astronomical figure. That is more ore than all the coal in the world could smelt; at its supposed grade of 30 per cent. metallic iron, it would make 2,400,000,000,000 tons of pig iron, enough to maintain the present output of the United States for 60,000 years.

The supposition that the Mesabi and Gogebic may be one and the same bed is based on the identity of the rock succession which persists down to almost all details. In each case a basal sandstone (now a quartzite) is overlain by a solid mass of iron formation 400 to 800 or even 1200 feet thick, followed by a huge mass of shales or slates. In each case in the middle of the iron formation there is a thin but persistent slaty seam or horizon which has an important influence on mining.

At any rate whether the Gogebic and Mesabi are identical or not the volume of the Huronian iron formation is enormous. I have mentioned the amount in trillions of tons to bring home the fact that the 900,000,000 tons already mined, added to the 2,000,000,000 tons more in sight, is only a minute fraction of the mass. The mining is done wholly upon the decayed fringes of the original deposits, mere shreds of them where the process of leaching and oxidation have produced natural concentrates. Should means be found of converting the unleached formation into artificial concentrates the iron ore supply of North America would be assured for more future time than the human animal has any reason to speculate about.

This remarkable area has lately been producing about eighty per cent. the iron of North America and nearly, or quite, half of that of the World. Minnesota yields about two thirds; Michigan and Wisconsin the remaining third. Although there are six "Ranges" in all, the Mesabi in Minnesota preponderates heavily over all the others combined. Thus in 1916, the year of record production to date, the output was as follows:

		Long tons
Minnesota	Mesabi	42,525,612
	Vermilion	1,947,200
	Cuyuna	1,716,218
Michigan	Marquette	5,396,007
	Menominee	6,364,363
	Gogebic	8,489,685
	Total	66,658,466

The total production to the end of 1918 is approximately as follows:

Mesabi, from 1892	490,000,000
Vermilion, from 1884	43,000,000
Cuyuna, from 1911	10,000,000
Marquette, from 1855	130,000,000
Menominee, from 1877	115,000,000
Gogebic, from 1885	110,000,000
Grand Total	898,000,000

These ores are high grade, averaging about 50% iron in thier natural state that is with the moisture, and about 56 per cent. dry.

In the former edition of this volume little was said about mining on the "Old Ranges" *i.e.*, all except the Mesabi and Cuyuna, but in 1911 a survey published by the State Board of Tax Commissioners of Michigan gave a great deal of information on the subject. Since this is the only authoritative data to be had on a very large group of mines, I am adding a summary of it.

It will be seen that the figures about to be given represent the mining on all the Ranges except the Mesabi and therefore account to date for more than 400,000,000 tons. Perhaps all these mines taken together have been worked out to an average depth of 1000 ft. Their production is about 400,000 tons per vertical foot. If all these ore-bodies, constituting no less than 200 mines, were put together they would make one grand body the horizontal cross section of which would only be about 120 acres in area. Some ore bodies are worked jointly by two or more mines; but not commonly enough to alter radically the conclusion to be drawn from the statement just made *i.e.*, that the ore-bodies are not exceedingly large and are scattered over a very large territory. There are indeed some very large deposits among them, or aggregates of ore bodies, for when large they are seldom simple. Of such the largest is the series of bodies worked by the Norrie, Newport and Ashland mines on the Gogebic. These have been followed to a depth of about 2400 feet and have yielded about 60,000,000 tons in 35 years. The next largest individual mine is the Chapin on the Menominee Range, which has produced in 40 years some 21,000,000 tons. There is scarcely an individual deposit on the Marquette Range that has yielded 10,000,000 tons during the 60 years life of that district. These conditions are reflected in the relation of "ore in sight" to production.

	Ore reported in sight 1911	Ore shipped 8 years 1911–1918 inclusive	Per year
Gogebic	17,354,000	45,660,000	5,700,000
Marquette	50,288,000	32,870,000	4,109,000
Menomince	20,579,000	39,800,000	4,975,000
Total	88,221,000	118,330,000	
Average output per year	....	14,790,000	

From this table it will appear that these mines do not differ very much from fissure-vein sulphide mines in the matter of blocking out ore. They seem to keep only 3 or 4 years supply developed. The Marquette Range is an exception; there ore indicated by drilling was reported, chiefly by the Cleveland-Cliffs Iron Company. Even here the reserve was only 12 years life.

I have not inquired closely into the discoveries of new ore in these districts since 1911, but judging from the way they maintain or increase their output the date of exhaustion must be a long way off. One or two important new mines and several important ore bodies have been discovered on the Gogebic and there is no doubt that this range will greatly exceed any expectation I was able to hold for it in 1911. Whether the others will exceed expectations similarly remains to be seen, but I regard it as probable.

District	Tons	General expense	Construction, development and exploration	Mining	Total	Total per ton
No. 1. Gogebic Range......	15,711,053	$1,558,705	$4,083,864	$21,207,105	$26,849,675	$1.72
No. 2. Iron County........	3,999,457	352,688	3,574,038	5,211,894	9,138,622	2.28
No. 3. Crystal Falls........	6,777,255	437,288	1,789,786	6,565,400	8,792,475	1.28
No. 4. Menomince Range...	10,052,564	971,447	1,915,320	11,289,470	14,176,237	1.42
No. 5. Baraga County......	744,603	48,919	159,844	951,722	1,160,486	1.56
No. 6. Marquette Hard Ores	4,078,863	582,605	1,173,335	6,801,080	8,557,021	2.10
No. 7. Marquette Soft Ores.	11,354,811	1,395,899	2,140,866	15,107,981	18,644,746	1.64
No. 8. Swanzy.............	2,095,723	112,674	307,771	33,312,786	3,793,231	1.81
No. 9. Scattered Low Grade.	1,293,658	59,960	279,101	845,056	1,184,119	0.92
Total....................	56,107,987	$5,580,185	$15,423,925	$71,292,494	$92,296,612	
Cost per ton.............		$0.10	$0.275	$1.27	$1.645	$1.65

This table shows the total output and costs of all Michigan iron mines for five years 1906–1910 inclusive, in long tons. The external operating conditions are about the same throughout the field; rigorous winters, cool summers a vigorous population, and reasonably cheap living.

I believe it is correct to say that a considerable portion of the "General Expense" and "Construction" in this table is represented in the discussion of the U.S. Steel Corporation's business[1] as general expense and depreciation; that is, as overhead or capital charges. These figures are undoubtedly complete in the aggregate, but it is not possible to do more than generalize roughly on the details because the different companies did not report their expenditures in the same manner; one would group all construction in a lump, perhaps even include it all under the general head of "mining," while others would separate it in detail; but still those who did this might employ different groupings. If construction represents in general the depreciation of fixed equipment, and if the depreciation is 6 per cent. a year, we may arrive at the conclusion that the capital thus employed in the Michigan iron mines is about $2.50 per annual ton. Fifteen cents per ton seems to be about the amount of actual construction. Other details will appear in the tables for the separate districts.

The total number of men employed was reported at 16,024, with some apparently not very important omissions. The average output was

[1] See following chapter.

11,200,000 tons so that the output per man was 700 tons per year. The total cost per man per year was $1150 at the mines; the actual wages and salaries $730 per man per year, being about 64 per cent. of the total cost, and averaging $2.40 per working day.

Under the conditions of 1918 it is probable that these factors indicate average costs at the mines of $3 per ton, or more, and total costs (about $1.70 freight added) at the lower lake ports approaching $5.

District No. 1. Gogebic County, Michigan

Number of mines and explorations reported	20	
Wages and salaries paid	$16,632,296.40	
		Per ton
General expenses (not including taxes)	$1,558,705.93	$0.098
Construction, development and explorations	4,083,864.20	0.260
Mining expense	21,207,105.10	1.355
Total cost at mine	$26,849,675.23	$1.72
Rail freights paid	6,002,288.37	0.40
Lake freights paid	10,585,921.64	0.71
Commissions paid	695,520.57	0.046
Total expense	$44,133,405.81	$2.876* f.o.b. Cleveland.

Total tons sold	14,183,842
Total tons shipped	15,393,642
Total tons mined	15,711,053
Total tonnage reported in sight	17,354,100

Receipts from sale of ore	$65,694,536.07
Total operating profit of 12 mines	21,944,683.57
Taxes	992,272.42
Proportion taxes to operating profits (per cent.)	4.55
Royalties	5,960,403.65
Profit to companies (12 mines)	15,212,854.39
Total profits 12 mines including royalties	20,957,419.53
Total loss to three mines (exploration and development properties not included	678,579.85

This district is about the best and most profitable among the "Old Ranges." Its ores are prevailingly Bessemer and run about 62% metallic iron, dry, and from 51 to 56% natural. These facts are reflected in the profits which, including royalties averaged about $1.33 per ton, or 30% of the average selling price at Cleveland.

District No. 2. Iron County, Michigan

Number of mines and explorations reporting	29	
Wages and salaries paid	$ 4,411,151.48	
		Per ton
General expenses (not including taxes)	352,688.21	$0.087
Construction, development and explorations	3,574,038.89	0.895
Mining	5,211,894.90	1.30
Total cost at mine	$9,138,622.10	$2.282

* The average cost per ton includes mines worked at a loss.

Rail freights paid		1,279,487.98	$0.40
Lake freights paid		1,609,055.90	0.54
Commissions paid		260,351.01	0.067
Total expense		12,287,516.99	$3.289* f.o.b. Cleveland.
Total tons sold	3,848,325		
Total tons shipped	3,820,308		
Total tons mined	3,999,457		
Total tonnage reported in sight	10,169,213		
Receipts from sale of ore		$12,740,286.82	
Total operating profit of 9 mines		2,044,106.72	
Taxes		103,907.11	
Proportion of taxes to operating profit (per cent.)		5.5	
Royalties paid		844,038.89	
Profits to companies (7 mines)		1,395,354.01	
Total profits 9 mines (including royalties)		1,952,543.49	
Total loss to companies (10 mines)		1,912,320.91	

This district produces only non-bessemer ores of rather low grade, seldom running over 56% dry and about 50% natural. The profits are only 15% of the selling price.

District No. 3.—Crystal Falls

		Totals	Per ton
Number of mines and explorations reporting		25	
Wages and salaries paid		$ 4,756,223.68	
General expenses (taxes not included)		437,288.47	$0.064
Construction, development and explorations		1,789,786.65	0.26
Mining		6,565,400.84	0.956
Total cost at mine		8,792,475.96	$1.28
Rail freights paid		2,374,293.64	0.40
Lake freights paid		3,267,453.98	0.57
Commissions paid		548,504.29	0.09
Total expense		$14,982,727.87	$2.34*
Total tons sold	6,050,662		
Total tons shipped	6,119,177		
Total tons mined	6,777,255		
Total tonnage reported in sight	1,233,900		
Receipts from sale of ore		$20,861,190.27	
Total operating profit (10 mines)		6,361,951.98	
Taxes		131,493.43	
Proportion of taxes to operating profits (per cent.)		2.6	
Royalties paid		1,611,190.15	
Profits to companies (8 mines)		4,846,463.22	
Total profits (10 mines) including royalties		6,238,753.13	
Total loss to companies (6 mines) not including explorations		710,684.40	

While this district produced only low-grade ores, such as those of district No. 2, the mines were remarkably profitable owing to some very low costs. The profits averaged over 26 per cent. on the selling price.

* Includes unprofitable mines.

District No. 4.—Old Menominee Range

		Totals	Per ton
Number of mines and explorations reporting		12	
Wages and salaries paid		$ 9,322,449.20	
General expense (not including taxes)		971,447.21	$0.097
Construction, development and explorations		1,915,320.33	0.192
Mining		11,289,470.33	1.128
Total cost at mine		14,176,237.87	$1.417
Rail freights paid		3,483,420.04	0.40
Lake freights paid		5,369,237.62	0.60
Commissions paid		66,661.27	0.07
Total expense		23,096,556.80	$2.487
Tons sold	9,391,360		f.o.b.
Tons shipped	9,335,812		Cleveland
Tons mined	10,052,564		
Total tonnage reported in sight	9,177,348		
Receipts from sale of ore		$34,103,131.46	
Total operating profit of ten mines		11,040,230.75	
Taxes		795,696.22	
Proportion of taxes to operating profit (per cent.)		7.24	
Royalties paid		2,395,619.41	
Profit to companies (9 mines)		7,885,624.86	
Total profit (9 mines)(including royalties)		10,249,066.96	
Total loss to companies, two		69,365.83	

This district produces generally fairly hard ores, partly Bessemer and partly non-Bessemer. The costs average low, both for local expenses and for freight, and ore was delivered at Cleveland for only $2.48 per ton for all operating and construction charges. The average profit, including royalties, was $1.10 per ton, 30 per cent. of the selling price.

District No. 5.—Baraga County, Michigan

		Totals	Per ton
Number of mines and explorations reporting		3	
Wages and salaries paid		$ 565,969.48	
General expenses (not including taxes)		$ 48,919.32	$0.065
Construction, development and explorations		159,844.44	0.214
Mining		951,722.56	1.28
Total cost at mine		$1,160,486.32	$1.56
Rail freights paid		228,479.12	0.35
Lake freights paid		398,492.21	0.61
Commissions paid		40,147.35	0.06
Total expense		$1,827,605.00	$2.58
Tons sold	657,370		
Tons shipped	657,370		
Tons mined	744,603		
Tons reported in sight	1,864,185		

Receipts from sale of ore	$1,807,495.98
Total operating profits, three mines	45,377.44
Taxes	7,331,05
Proportion of taxes to operating profit (per cent.)	16.2
Royalties paid	136,601.62
Profits to companies (3 mines)	None
Total profits three mines (including royalties)	36,046.39
Total loss to companies, three mines	98,555.23

This district is in the upper Huronian at the west end of the Marquette Range. It is of slight importance.

District No. 6.—Marquette County, Michigan

		Totals	Per ton
Number of mines and explorations reporting		11	
Wages and salaries paid		$ 5,296, 704.30	
General expenses (taxes not included)		582,605.38	$0.14
Construction, development and explorations		1,173,335.39	0.29
Mining		6,801,080.83	1.67
Total cost at mine		$ 8,557,021.60	$2.10
Rail freight paid		1,230,335.82	0.40
Lake freight paid		2,359,387.30	0.60
Commissions paid		59,900.93	0.02
Total expense		$12,206,645.65	$3.12
Tons sold	3,873,785		
Tons shipped	3,888,557		
Tons mined	4,078,863		
Tons reported in sight	11,134,355		
Receipts from sale of ore		$17,015,407.56	
Total operating profit, 6 mines		5,246,934.10	
Taxes		496,505.01	
Proportion of taxes to operating profit (per cent.)		9.45	
Royalties paid		262,329.14	
Profit to companies, 6 mines		4,723,752.76	
Total profits, 6 mines (including royalties)		4,866,081.90	
Total loss to companies, 2 mines		572,825.00	

This district includes many of the oldest and most famous mines in the Lake Superior District—the "hard ore" mines of Marquette, such as the Republic, Champion, Lake Superior and Cleveland. These ores occur along the unconformable contact of the Middle Huronian iron formation and the basal quartzite of the Upper Huronian. Very probably this ore represents oxidation and concentration on an ancient land surface—at least to a considerable extent.

District No. 7.—Marquette County, Michigan

	Totals	Per ton
Number of mines and explorations reporting	20	
Wages and salaries paid	$12,011,515.90	
General expenses (not including taxes)	1,395,899.35	$0.12
Construction, development and explorations	2,140,866.05	0.19
Mining	15,107,981.23	1.33
Total cost at mine	$18,644,746.63	$1.64

Rail freight paid		3,064,947.71	0.32
Lake freight paid		5,424,983.28	0.65
Commissions paid		134,029.88	0.01
Total expense		$27,268,707.50	$2.62
Tons sold	10,744,791		
Tons shipped	10,830,611		
Tons mined	11,354,811		
Tons reported in sight	35,961,538		
Receipts from sale of ore		$39,605,117.47	
Total operating profits, 15 mines		12,467,025.65	
Taxes		865,028.59	
Proportion taxes to operating profit, per cent		6.98	
Royalties paid		1,859,944.05	
Profit to companies, 13 mines		9,867,181.86	
Total profits, 14 mines (including royalties)		11,654,992.00	
Total loss to companies, 4 mines		255,584.53	

This district covers most of the soft ores of Marquette; bodies formed by leaching from the surface along channels of free circulation of water. They are concentrations in the body of the Middle Huronian iron formation, generally upon some impervious rock layer bent into a trough-like form.

District. No. 8.

		Totals	Per ton
Number of mines and explorations reporting		13	
Wages and salaries paid		$2,158,212.35	
General expense (not including taxes)		172,674.60	$0.082
Construction, development and explorations		307,771.22	0.148
Mining		3,312,786.07	1.580
Total cost at mine		$3,793,231.89	$1.81
Rail freights paid		311,706.73	0.32
Lake freights paid		418,475.85	0.65
Commissions paid			
Total expense		$4,523,414.47	$2.78
Tons sold	1,669,737		
Tons shipped	1,670,263		
Tons mined	2,095,723		
Total tonnage expected	6,746,158		
Receipts from sale of ore		$5,682,757.47	
Total operating profit, 6 mines		1,267,967.36	
Taxes		99,687.11	
Proportion of taxes to operating profit (per cent.)		7.9	
Royalties paid		540,348.62	
Profit to companies, 1 mine		1,047,803.59	
Total profit,2 mines (including royalties)		1,219,975.79	
Total loss to companies, 3 mines		528,496.32	

This is a small outlying basin of the Marquette Range, known as the Swamzy district. Presumably its geology is some variation of that of district No. 7.

District No. 9.—Various Scattered Low-grade Mines.

		Totals	Per ton
Number of mines and explorations reporting		11	
Wages and salaries paid		$ 620,145.06	$0.44
General expenses (taxes not included)		59,960.53	$0.045
Construction, development and explorations		279,101.91	0.22
Mining		279,101.91	0.22
Total cost at mine		$1,184,119.36	$0.925
Rail freights paid		$ 454,062.59	$0.40
Lake freights paid		502,930.70	0.60
Commissions paid		72,834.61	0.10
Total expense		$2,213,947.26	$2.025
Tons sold	1171,024		
Tons shipped	1179719		
Tons mined	1,293,658		
Tons reported in sight	1,323,074		
Receipts fom sale of ore		$2,261,830.18	
Total operating profit, 4 mines		386,208.35	
Taxes		21,327.20	
Proportion taxes to operating profit (per cent		5.45	
Royalties paid		154,427.35	
Profit to companies, 4 mines		278,364.85	
Total profit (including royalties)		374,323.47	
Total loss to companies, 5 mines		406,235.48	

These mines are not a district, but partial concentrations in various places.

If this set of figures represents the average proportion of things in the iron mining business of the Old Ranges we find that the average profit, including royalty, is about 12 per cent. of the value of the contained pig iron at Pittsburgh. A large proportion of the mines are leaseholds, paying royalties to the owners of the fee. Where royalties are paid on average ore they will be perhaps 30 cents a ton.

Vaue of ore at Cleveland		$3.80
Cost of mining, construction, exploration	$1.65	
Transportation	1.07	
Taxes	.07	
All costs		$2.79
Gross operating profit		1.01
Royalty		0.30
Profit to leaseholder		$0.71

Average content of ore in iron (natural) 54 per cent. Value of this pig iron in Pittsburgh about $8.64. Value of ore at Cleveland compared

to the value of its metallic contents made into pig iron at Pittsburgh, about 44 per cent.

Profit on capital invested in plant about 28 per cent. The entire capital invested must be very much greater than that represented by the plant. It would have to include either the cost of finding a mine by exploration, or else a purchase price for a developed mine, or both.

It must of course be reiterated that none of these figures represent the costs ruling in 1919 which are no doubt 40 to 50 per cent. higher than those given. Under present conditions the price of these ores should be about $6.00 a ton to maintain the business in approximate equilibrium.

Table I.—Lake Superior Iron-ore Shipments

(In Long Tons)

	1916	1917	1918
Escanaba	7,457,444	7,156,854	6,774,969
Marquette	3,858,092	3,207,145	3,457,054
Ashland	8,057,814	7,597,841	7,565,608
Two Harbors	10,735,853	9,990,901	8,723,472
Superior	12,787,046	13,978,741	14,068,341
Duluth	21,837,949	20,567,419	20,567,288
Totals by lake	64,734,198	62,498,901	61,156,732
Totals all rail (est.)	1,924,268	1,938,102	2,000,000
Total shipments	66,658,466	64,437,003	63,156,732

Table II.—Monthly Production of Coke and Anthracite Pig Iron in the United States, Beginning Jan. 1, 1914

(In Long Tons)

	1914	1915	1916	1917	1918
January	1,885,054	1,601,421	3,185,121	3,150,839	2,411,768
February	1,888,670	1,674,771	3,087,212	2,645,247	2,319,299
March	2,347,867	2,063,834	3,337,691	3,251,352	3,213,091
April	2,269,655	2,116,494	3,227,768	3,334,960	3,288,211
May	2,092,686	2,263,470	3,361,073	3,417,340	3,446,412
June	1,917,783	2,380,827	3,211,588	3,270,055	3,323,791
July	1,957,645	2,563,420	3,224,513	3,342,438	3,420,988
August	1,995,261	2,779,647	3,203,713	3,247,947	3,389,585
September	1,882,577	2,852,261	3,202,366	3,133,954	3,418,270
October	1,778,186	3,125,491	3,508,849	4,303,038	3,486,941
November	1,518,316	3,037,308	3,311,811	3,205,794	3,354,074
December	1,515,752	3,203,322	3,178,651	2,882,918	3,433,617
Totals (*a*)	23,049,752	29,662,566	39,039,356	38,185,981	38,506,047

(*a*) Totals do not include charcoal pig iron. Figures secured from *Iron Age*.

TABLE III.—PIG-IRON PRODUCTION (*a*) FOR 15 YEARS

(In Long Tons)

1904	16,497,003	1909	25,795,471	1914	23,332,244
1905	22,992,380	1910	27,303,567	1915	29,916,213
1906	25,307,391	1911	23,649,547	1916	39,434,797
1907	25,781,381	1912	29,726,937	1917	38,621,216
1908	15,936,918	1913	30,966,152	1918 (*b*)	38,820,000

(*a*) American Iron and Steel Institute.
(*b*) Estimated.

TABLE IV.—PIG-IRON PRODUCTION BY GRADES

Grades	1917		1918(*a*)	
	Long tons	Per cent	Long ton	Per cent
Basic	17,671,662	45.8	18,361,860	47.3
Bessemer	13,714,732	35.5	12,810,600	33.0
Foundry	5,328,258	13.8	5,357,160	13.8
Malleable	1,015,579	2.6	1,281,060	3.3
Forge	345,707	0.9	427,020	1.1
Spiegeleisen	171,675	0.5	194,100	0.5
Ferromanganese	281,425	0.7	310,560	0.8
All other	92,168	0.2	77,640	0.2
Totals	38,621,216	100.0	38,820,000	100.0

(*a*) Estimated.

CHAPTER X

COST OF MINING LAKE SUPERIOR IRON MESABI RANGE AND U. S. STEEL*

IMPORTANCE OF THE DISTRICT—GENERAL STATEMENT OF THE COST PROBLEM—THE UNITED STATES STEEL CORPORATION—CAPITAL EMPLOYED IN MINING, TRANSPORTATION, AND BLAST FURNACES—WORKING CAPITAL—TREATMENT OF CAPITAL CHARGES—IRON MINES AND ROYALTIES—COST OF MINING—OLD RANGES AND THE MESABI RANGE—COST OF OPEN-PIT OPERATIONS—ENGINEERING AND MANAGEMENT—TAXES—ECONOMY OF CONSOLIDATION—ESTIMATE OF AVERAGE MINING COST—TRANSPORTATION—ESTIMATES OF SELLING COST OF PIG IRON AT PITTSBURGH—STATISTICAL RECORD OF UNITED STATES STEEL CORPORATION—ITS CAPITAL CHARGES AND INCREASED CAPACITY—ITS PROFITS—ITS PLANTS AND PROPERTY—REVIEW OF OPERATIONS OF STEEL CORPORATION 1909–1918.

When people speak of the output of metal mines in general they mean the gross selling value of the refined metals of New York. Now the value of Lake Superior iron ores is never given in mass. You hear of the value of bessemer, or non-bessemer, old range or Mesabi ores at the mines or at Cleveland, but you do not hear of average values nor of gross values in pig iron.

But if we make a correct comparison of the importance of various districts on the basis of the value of their products in New York in 1918, we shall see that Lake Superior pig iron transcends them all.

Lake Superior copper	$ 53,000,000
Southeast Missouri lead	25,000,000
Southwest Missouri zinc	32,000,000
Butte copper	80,000,000
Southwestern copper	210,000,000
Transvaal gold	179,000,000
Lake Superior iron	1,150,000,000
Mesabi Range alone	760,000,000

The business is profitable, one of the most profitable in the world, on account of its volume, but it is not easy to give precise figures concerning it. Much has been written on the various problems involved, such as the caving system of mining, the systems of accounting, mining open pits, blast-furnace practice, etc., but each of these is only a link in the chain. I have never found any comprehensive discussion of the subject as a whole. I have, therefore, endeavored to work out on an

*The first part of this chapter was written in 1909, the latter part in 1919. Some of the comparative figures may be somewhat out of date to-day, but I hope not to a great enough extent to convey any serious false impression.

original basis a statement of the cost of operating this vast business. It may be interesting to explain the method.

General Statement.—The first thing to decide is what to include in the cost. At present, it is not a matter of any particular interest to have details of the mere cost of extracting ore from some particular iron mine and dumping it on the surface, although before the absorption of most of the mines by the various steel and furnace corporations the local mining costs were indeed a subject of interest. There were then many companies which only mined the ore and sold it at the pit mouth.

At the present time by far the greater part of the ore is mined by concerns which use it to make pig iron and, in many cases, finished manufactured steel or iron products. To describe this industry in parallel terms to those used in the case of other metals it seems to me that we should find the cost of pig iron delivered at New York. It is quite true that New York is not the greatest market for pig iron, but since I have discussed other metals on the theory of their delivery there it is reasonable to follow the same plan with iron.

The reason for stopping with the production of pig iron is simply the analogy of other metals. Pig iron is the basic commodity of iron manufacture. It bears the same relation to the making of steel rails or pocket knives as blister copper slabs bear to the making of copper wire or brass door knobs, or as pig lead bears to lead pipe or buck-shot. As I shall try to show what it costs to produce from various districts copper lead, and zinc ready for manufactures, so I shall try to show the cost of bringing Lake Superior iron to the same stage.[1]

Complexities of the Problem.—When we give this problem some attention we soon find it rather complex. The ore comes from scores of different mines, each producing its own particular grade at its own particular cost. But the cost of getting ore out of the mine is considerably less than that of transporting the ore from the mines to the furnaces, although the cost of transportation varies considerably according to the situation of the mine. We find that in some cases large royalties are paid to fee owners and in other cases the mining company owns the ground. These various factors are bewildering. Furthermore none of the companies gives its costs.

The United States Steel Corporation, however, issues very good

[1] In this chapter I have assumed in regard to the United States Steel Corporation that the profits on ore hauled by others will be counterbalanced by profits earned by the coporation on ore hauled for others, so that the final result with regard to this transportation will be the same as if all the ore mined by this company were transported by the company. I have also assumed that the making of pig iron at Pittsburg is representative in cost, and that pig iron can be made at Pittsburg and sold at New York for as low a price as pig iron made at other points and shipped to New York. All tons are of 2240 pounds.

reports. These and various isolated data published by the U. S. Geological Survey, and such information as I could get from personal observation, are the sources from which my conclusions are derived. The Steel Corporation is fully as much a manufacturing as a mining concern and even buys some of its pig iron from others. It does not stop with pig iron. It makes steel rails, sheets, wire, rods, and even spelter and cement. It is the greatest of all industrial enterprises, employing in good times more than 200,000 men. Naturally the reports of such a corporation must be condensed. As a matter of fact no operating data of any kind are given. The omission is in this case quite proper. The production, the earnings, the capital expenditures, the property holdings, are all given. This information seems at first insufficient for any definite statement of costs, but it is all that can be had. On two recent trips to the Mesabi range, I saw a good deal of the mines, but I enjoyed no confidences. My inquiries were such as any one could easily make. I make this explanation in order that no one may be under a misapprehension. The basis for the statements I am about to make is what I believe to be common sense.

Activities of the United States Steel Corporation.—The operations of the Steel Corporation are undoubtedly representative of the Lake Superior iron business—far more so than those of any other concern. It mines and ships 55 per cent. of the whole product. It owns two of the three ore railroads in Minnesota and the shipments over its roads are 52 per cent. of the whole Lake Superior output. Just what proportion of the ore is transported on the lakes by the company's boats I do not know. When we come to pig iron we find that the company produces an amount equivalent to 55 per cent. of the probable content of Lake ores. It seems to have about 75 per cent. of the known ore reserves of the region. We may conclude, therefore, that this company performs about 55 per cent. of the business all along the line, and that its costs would be approximately the same if it did all the business.

One might argue that the costs of the Steel Corporation are radically different in some respects from those of the independents. For instance, an independent may have to pay 80 cents a ton for freight that costs the Steel Corporation only 40 cents. It is for this very reason that the Steel Corporation is most representative. Its business is complete; that of the others, fragmentary. Just as the independents expect a profit on the ore that they own, so they must expect to pay a profit on the transportation that they do not own. It would be next to impossible to work out the real cost of pig iron if we tried to discover and weave together the obscure and disjointed costs and profits of a chain of discordant operators.

Capital Employed at Iron Mines.—Fot the purpose of this article the capital employed is one of the most vital elements to consider. Remembering that we are to obtain our costs on pig iron and not on finished

products, we must segregate the capital used in manufacturing from that used in mining and smelting. This can be done only approximately. Probably no one could make the division with absolute certainty, for it is necessary to remember that transportation, fuel, and power facilities owned by the company are used for the joint purpose of manufacturing steel products and of producing pig iron. I am, therefore, compelled to make a division on my own judgment, and in order to enable the reader to estimate the legitimacy of this judgment, it is necessary to show the method of arriving at it.

The corporation owns in the Lake Superior region 72 iron mines of which 10 are on the Marquette range, 10 on the Menominee, 6 on the Gogebic, 6 on the Vermilion, and 40 on the Mesabi range. Neglecting the purchase price of the properties, and considering only the actual money invested in the plants for the machinery, developments, etc., I make a rough guess that the total capital employed would be somewhat as follows:

Old ranges, each $2,500,000	$10,000,000
Mesabi range	25,000,000
Invested in extensive exploration and developments in the whole Lake Superior region	15,000,000
Total investment	$50,000,000

Capital Employed in Transportation.—The Duluth & Iron Range railroad and the Duluth, Missabe & Northern railroad with a total of 363 miles of main line would be indispensable to the conduct of this business, even if it did not extend beyond the production of pig iron. We may calculate the value of this property at $50,000 to the mile, or in round numbers $18,000,000. The Elgin, Joilet & Eastern railroad and various small lines near the manufacturing plants, with a total length of about 295 miles, may be estimated to belong half to the production of pig iron and half to manufacturing. I would charge, therefore, $7,000,000 in round numbers for these lines. The Bessemer & Lake Erie railroad, with 205 miles of lines, I would charge entirely to the production of pig iron, and capitalize it at $10,000,000. This figures up a total of $35,000,000 for railroad tracks. In addition to this we have the railroad equipment which I estimate at $52,500,000, out of which $40,000,000 would be necessary for the production of pig iron alone. We have then a total for railroads and their equipment of $75,000,000.

The marine equipment consists of 76 steamers and 29 barges. Many of these steamers are the largest and best upon the lakes, and some of them undoubtedly cost $700,000 or $800,000 each. I should say that the total equipment must be worth $40,000,000.

Capital Employed in Coal and Coke Properties.—We have in the Connellsville and neighboring regions 62,253 acres of coal lands and 20,471

coke ovens. I believe it would be conservative to estimate the capital employed there at $30,000,000. In the Pocahontas district there is a lease on 65,947 acres on which are 2151 coke ovens. This property must have cost somewhere in the neighborhood of $10,000,000 for its development.

There are in addition 31,928 acres of steam-coal ground in Pennsylvania, West Virginia, and Ohio. I would estimate the valuation of the plants employed on these properties to be at least $5,000,000. We have then a total of $45,000,000 for coal and coke plants. Of this I should say $35,000,000 would be necessary for the conduct of the pig-iron business of the corporation.

Capital in Blast Furnaces.—The corporation owns, exclusive of its properties in the South, 100 blast furnaces, many of them the largest and best in the world. This property may be estimated at $110,000,000.

For the handling and shipping of iron ore, coke, and coal, the corporation owns a large number of extensive docks, the total value of which I would guess at $20,000,000.

Capital in Inventory and Surplus.—At the end of 1908, the inventory of the Steel Company was given at $143,000,000, of which nearly $66,000,000 was in ore. It seems to be a fair deduction from this, if its business were only making pig iron one-half the grand total would be necessary—say $70,000,000. At the same time the surplus was given at $133,000,000, of which, however, $78,000,000 had been invested on plant account, leaving a cash balance of something over $50,000,000. We may assume that, inasmuch as the selling price of pig iron is about one-half of that of the finished products—one-half of this cash surplus would be required in the business of making pig iron—say $25,000,000, making a total working capital of $95,000,000.

Summary of Capital Used.—We may summarize the capital as follows:

Iron mine plants and development	$ 50,000,000
Plants for transportation of iron ore	115,000,000
Coal, coke, and quarry plants	35,000,000
Docks and dock equipment	20,000,000
Blast furnaces	110,000,000
Total fixed capital	$330,000,000
Working capital in inventory and surplus	95,000,000
Total capital	$425,000,000

It is to be noted that this estimate does not include the purchase price of lands or good-will, but only such capital as would be required is the opportunity to conduct this business were a free gift. Capital so employed is worth in round numbers 5 per cent. interest plus a sinking und, calculated to retire the principal in about forty years. Such a

fund is equal to about 1 per cent. additional. We must calculate the use of this capital then at 6 per cent., and this is not profit. It is merely the actual value of the money employed—such a return as can be secured by an investor without burdening himself with the management of an enterprise. In the case of the Steel Corporation by far the greater portion of this capital is actually represented by 5 per cent. bonds to be retired by a sinking fund substantially on the terms indicated above. We must therefore include as an operating cost of this business an annual installment of 6 per cent. on $330,000,000 equal to $19,800,000. On an output of 10,000,000 tons of pig iron a year this is $1.98 a ton.

In addition to this we must make a charge for depreciation which is usually represented by new construction. It is generally believed that depreciation on the kind of property in question will amount to some 6 per cent. per annum. But in this case the entire plant is not in use. The above investment provides capacity for nearly 15,000,000 tons of pig iron a year, but as we are calculating on a product of only 10,000,000 or two-thirds capacity it seems fair to charge depreciation only on two-thirds of the capital invested or $220,000,000. Six per cent. on this amount will make an annual installment of $13,200,000.

The working capital should be charged with an average rate of interest—say 5 per cent. This on the $95,000,000 calculated to be the amount makes an annual installment of $4,750,000.

The cost, then, of making pig iron should be charged with the following sums for amortization of fixed capital:

For amortization of fixed capital	$19,800,000
For depreciation	13,200,000
For interest on working capital	4,750,000
Total capital cost per annum	$37,750,000

Equal to $3.77 per ton on the assumed output.[1]

[1] These figures are different from those calculated in an article on this subject of which the present chapter is substantially a reprint. In that article the total capital was estimated at $475,000,000, on which an amortization charge of 6 per cent. or $28,400,000 was made. Further investigation has revealed some inaccuracies in this calculation, principally in the items of working capital and in the value of blast-furnace property.

Furthermore, the present treatment of the subject seems more logical and more in accordance with the calculation of smilar costs of our other industries, treated in other chapters.

In the article mentioned I assumed a royalty charge of 40 cents per ton. In this chapter this has been cut down to 20 cents, the estimate made by Mr. Carnegie as the actual payments made on the present arrangements by the corporation on all its ores; the change is made on the theory that the amortization of capital and the depreciation of the plants calculated for the mining properties are sufficient to cover the royalty that a company legitimately charged itself with. In other words, I am trying to account for the expenditures which it seems the company actually makes.

The Iron Mines.—Let us return to the source of operations and consider what iron-ore resources the company owns. According to the reports of the Minnesota Tax Commission the various properties owned by the Oliver Iron Mining Company on the Mesabi range have in sight 920,000,000 tons. This, I believe, is an estimate only of those ores which are at present merchantable. The large quantities of lower-grade ores on the western portion of the Mesabi range, which depend upon concentration for their utilization, have not, I believe, been reported. The discoveries of this kind of ore are very extensive, and as experiments have gone to the point of demonstrating the practicability of concentrating them, these ores should be considered as a resource. What the total volume of such ores may be I can only guess, but I should say that it would not fall far short of 300,000,000 tons of concentrates, making a total of probable ore on the Mesabi range of 1,220,000,000 tons.

As to the ore resources on the old ranges I have no means of making an estimate. It is to be remembered that these mines extend to great depths and that the exploration of them in advance is not easy, but on the other hand many of them are exceedingly persistent and have already been worked for a great many years with no signs of exhaustion. Assuming that these mines may be counted on to produce as much in the future as they have in the past, we get an estimate of 114,000,000 tons for the old ranges, that is, outside of the Mesabi range. Therefore, I would estimate, in round numbers, the total ore resources of the Steel Corporation in Lake Superior at 1,300,000,000 tons.

It will be seen that I have estimated for the exploration and finding of these ores, outside of cost of mining plants in operation, $15,000,000. This seems to be an extremely moderate estimate of cost for putting in sight such enormous reserves, but as far as I can judge by the inquiries that I have made the sum is somewhere near the mark. Explorations on the Mesabi range have been extraordinarily fruitful, and the cost for drilling seems to be not much over 1 cent per ton developed.

Royalties.—A very large proportion of the ores controlled by the Steel Corporation is not held in fee, but under leases on which the company pays a varying rate of royalty. This royalty has shown a constant tendency to increase. Many of the earlier leases provide for a royalty of only 25 cents per ton and the leases were made for periods of 20 years or more. In some cases these leases are already near termination and new leases will have to be made at an advanced royalty. Some of the latest leases provide for royalties of 85 cents per ton on standard ores with provision for still further increases.

It is probable that under present conditions the company pays an average of not over 20 cents per ton, because a good deal of its ores are mined from its own lands, but it is manifestly unfair to the Steel Corporation not to allow for its own land a royalty equal to that which

it must pay to other owners. On this basis it is probable that the actual royalty allowable on the ore should be about 40 cents per ton.

On the theory that I have adopted for these articles, royalty is not wholly an operating cost, but is in a large part a profit paid to the owners of lands out of their exploitation. Accordingly I charge in this estimate only the 20 cents per ton actually paid to other owners and make up the difference to the Steel Company through the amortization of capital invested in its iron mines and explorations.

Cost of Ore from Old Ranges.—At present about two-thirds of all the ore from Lake Superior comes from the Mesabi range, but in the case of the Steel Corporation the proportion is over 74 per cent. It is probable that we would not be far wrong if we adopted a proportion of 70 per cent. from the Mesabi range and 30 per cent. from all the others. By making the above division we may make a reasonably close estimate of the cost of mining in the Lake Superior ores in general.

On the old ranges the problem is essentially uniform. That is to say, there is no great difference in mining ore on the Menominee range, or on the Vermilion range. In all cases the work is done entirely underground, usually at depth between 500 and 1500 ft. Individual mines, of course, show great variations. In some cases the ore is extremely hard and in other cases extremely soft. Some mines have one large body of soft ore; others have a number of comparatively small bodies of hard ore, but these individual differences occur about equally on all the ranges.

The cost may be estimated as a function of the output per man per day. In the case of the hard-ore mines, the output per man is as low as 2½ tons per man, while in some of the most favorable soft-ore mines the output exceeds 5 tons per man. Now, the average wages in the Lake Superior region for all men employed may be calculated at $2.60 per day. We may further estimate that wages account for approximately 60 per cent. of the cost at the mines.

It is probable that the actual operating cost may be calculated at the rate of $4.25 per man employed. On this basis, if a mine gets out 2½ tons per man, its operating cost will be $1.70 per ton; if it gets out 5 tons, its cost will be 85 cents. I believe the actual figures on the average would fall about half-way between these extremes, and that the average output for the old range mines would be somewhere near 3¾ tons per man. This would give a cost of about $1.15 at the mines, exclusive of taxes.

Costs on the Mesabi Range.—The cost of mining on the Mesabi range is determined almost absolutely by the depth of the surface covering. If the orebody is thin and the overlying surface deep, it is necessary to mine the ore by underground methods. In this case the cost of mining on the Mesabi will be approximately 90 cents per ton, the average output per man being 4½ tons.

Open-pit mining varies greatly in cost. This work is now done universally by means of steam shovels and the difficulty varies according to the proportion of overburden to ore, the texture of the ore, the proportion of boulders and tongues of country rock in the orebody, and the amount of water to be pumped. These various factors cause abrupt variations in the cost.

We may calculate that the removal of stripping costs 32 cents per yard. If one yard of stripping uncovers a yard of ore we will have one yard of ore containing 2½ tons mined at a cost of removing 2 yards of material, or 64 cents, making the mining cost 25.6 cents per ton of ore. To this cost, however, must be added the interest on capital invested in preliminary stripping and other costs of preliminary development of the mine, the cost of pumping and of certain general expenses that do not occur on the ground, so that when equal amounts of stripping and of ore are removed, I calculate that the cost will be decidedly over 30 cents per ton. This estimate does not include the taxes which I shall presently discuss separately.

It is evident that the proportion of stripping to the ore does not vary directly according to the relative thickness of the surface and the underlying ore; it is a function of these factors combined with several other factors. The glacial material is usually much more uniform in thickness than the orebodies underneath. The latter are usually trough-shaped with many irregularities at the sides and bottom. Furthermore, pits must have sloping sides so that in cases where the depth of the ore is equal to that of the overburden there will still be a considerably larger volume of overburden removed from the pit than there will be of ore. These considerations induce a good deal of caution on the part of operators in the question of deciding upon open-cut mining where the overburden is deep.

Open Cut *vs.* Underground Mining.—When the exact proportion of stripping to ore can be worked out, it is a simple question of arithmetic to figure where it will pay to adopt underground mining instead of open pits. As the cost of underground mining is about 90 cents per ton, when open-pit operations are cheaper than that, theoretically the mining should be done by the latter method. But a good many considerations come in to interfere with carrying this method to its logical limits. Among these may be pointed out the necessity of investing a large amount of money in excavating the over-burden before mining can be undertaken. In the case of companies that are financially weak this is a matter of considerable importance.

In many cases where open-pit mining would have been much cheaper, the ore has been mined underground because the mine could be opened more rapidly and a certain profit more quickly realized even though the operators knew that they were not securing the best costs. This argu-

ment does not apply to the Steel Corporation, of which the capital is abundant for undertaking operations in the most comprehensive way. As a matter of fact, it is in many cases resorting to open-pit methods at mines where formerly, under other owners, the work was done underground.

Exigencies of Open-Cut Operations.—At first glance it would seem as if when a yard either of ore or of waste can be dug out by steam shovels for 32 cents, that the cost per ton would be approximately 13 cents, and that, therefore, it would be as cheap to mine almost 7 tons in an open pit as it is to mine 1 ton underground. In other words, 6 tons of stripping might be removed to secure 1 ton of ore. This would be the case were there no expense involved in mining except the actual digging. As a matter of fact, there are other expenses that amount to considerable. One of these, the interest on the money thus locked up in stripping, I have already pointed out, but a still more important cause for hesitation in adopting open-pit mining to its full apparent limit is the considerable variation in the cost of steam-shovel work in different parts of the same mine. Where the ores are soft and uniform a steam shovel will undoubtedly dig a large amount of ore. In some mines the cost of digging ore for a period may go as low as 6 or 7 cents per ton, but this may be followed by another period when the costs may be several times as high.

For instance, in 1906, at the Mountain Iron mine an output of 2,560,000 tons was obtained with a force of 500 men. The bulk of the work was done in eight months, say 200 days. At an average cost of $4.25 per man per day we get for this period a total cost of about $425,000. Supposing that for the remainder of the year one-half the force was occupied, we must increase the estimated cost by about $125,000, making a total for the year of $550,000. This equals 21 cents per ton. In 1907, with an output of 1,973,000 tons, 1200 men were empoyed. This indicates a cost of more than 65 cents per ton.

A part of the increase was due, no doubt, to an additional volume of the stripping undertaken, but a considerable part of the increlase cannot thus be explained. In the orebody itself changes were encountered that not only diminished greatly the output per steam shovel, but also greatly increased the number of men employed per shovel. Up to 1906 the total number of men required in shops, train crews, track laborers, etc., per steam shovel never exceeded 75; since then it has been 100.

The reasons for this are: (1) The ore itself has become much harder, frequently breaking into great slabs and chunks that have to be sledged to make them suitable for reduction in the blast furnace. (2) Owing to the irregularity of the bottom of the deposit it is often impossible to provide adequate working faces for the steam shovels, so that along the bottom and sides the shovels frequently have to take shallow cuts, and sometimes the shovels suddenly run into worthless bars of rock.

When the last occurs, the machine must be moved to a new working place. (3) Boulder-like masses of worthless country rock occur in the ore which must be removed as waste. In a word the excavation of ore by steam shovels, after the stripping is all done, may be much more expensive than is popularly believed.

Unwatering the Open Pits.—The cost of pumping must be fully as high for open-pit as for underground mining and must be kept up just as steadily. The great pits form catchment basins, often many scores of acres in extent, and in the event of heavy rains, which are far from uncommon on the Mesabi range, the volume of water is often so great as to cause work to be suspended. Fortunately the ore is porous so that the pumping may all be done from a single shaft so located as to provide for the drainage of the entire orebody for all times. The volume of water ejected from a single orebody is frequently 5000 to 6000 gal. per minute. I estimate that when 5000 gal. per minute is pumped from a depth of 300 ft. and the output is 1,500,000 tons per year, the cost of pumping will be 7 or 8 cents per ton. I suppose this is about a maximum cost for the Mesabi.

Now, returning to the question of where open-pit work should end and underground mining should begin, we find that the conditions are about as follows: The actual cost of digging ore in a pit where the ore is hard and sorting is necessary may run up as high as 40 or 50 cents per ton. This cost will be reached when a steam shovel with a crew of 100 men at an average cost of $4.25 per day digs 20 cars, or between 800 and 1000 tons per day. The cost will not exceed 50 cents per ton, because ore can be sorted and loaded as cheaply as that by hand without any steam shovel. Let us then put 50 cents per ton as a maximum cost for digging.

The cost of administration, interest on development capital (largely stripping), and of pumping, is, of course, variable. Where 500,000 or more tons are mined in a year, all these expenses combined are not likely to exceed 15 cents. At the worst, then, we have 65 cents per ton as the cost of mining in open pits, outside of stripping. Now, as underground mining will cost 90 cents per ton, we have the difference between 90 cents and 65 cents to invest in stripping. This 25 cents will remove 2 tons of overburden.

I therefore conclude that it will pay to remove 2 tons of overburden to 1 ton of ore, under the least favorable mining conditions. Under the most favorable conditions, where both the ore and the overburden are soft and uniform, the economical proportion may rise as high as 4 or even 5 to 1.

Average Cost of Mining on the Mesabi Range.—This is a point on which no one can get exact information without access to the cost statements of at least fifty different properties, but in a general way I think

we can get a rough estimate that will be sufficient for practical purposes. It will appear that the actual mining cost of the ore at the mines is not, after all, one of the greatest factors in the final cost of producing pig iron.

Returning to our output per man per day as a basis for calculating costs I find that during 1907 the mines of the Steel Corporation in the Hibbing district produced approximately 9,000,000 tons of ore. This ore came largely from great open-pit properties, but some of it came from underground mines. I am informed that the total number of men employed was about 4500 with 60 steam shovels. Supposing that the whole of this force was employed for eight months, and half of it for the remaining four months of the year, and assuming that 26 working days constitute a month, we get an equivalent of 260 days with 4500 men, each costing \$4.25. This gives us a total of approximately \$5,000,000, or in round numbers, 55 cents per ton.

This estimate is open to doubt on several points, two of which are whether the amount of stripping that was done kept pace with or exceeded the amount of ore extracted, and whether the rough figures of labor employed are actually near the truth.

As to these facts I have no means of judging except the most general impressions, but I am satisfied that at the worst my information is not far enough astray to make the cost hopelessly inaccurate. In a general proposition of this kind no one attempts to get down to niceties, and there is no occasion for it. When I state that the average ore mined in the Hibbing district costs 55 cents per ton, I may be 15 or 20 per cent. astray this year, and next year I may be right.

The mines of Hibbing undoubtedly are the most favorable on the Mesabi range for cheap costs. They have the largest, softest, and most uniform orebodies, and are worked on the largest scale. It does not seem improper, therefore, that if we estimate the cost at 55 cents per ton at Hibbing, we should increase this to 60 cents for the whole range. I therefore estimate that the average cost of mining on the Mesabi range for both underground and surface is about 60 cents per ton, exclusive of taxes.

Taxes.—The laws of Minnesota tax mining properties for what ore they have in sight. The tonnage developed is reported by the mining companies to the assessor, who puts a valuation upon it according to the quality and accessibility of the ore. For purposes of taxation, discovered ores are placed in five or six different grades with a minimum valuation of 8 cents per ton and a maximum of 33 cents. Roughly, the ore developed seems to average about 15 cents per ton in valuation. This valuation is taxed just as any other assessed property is taxed, the levy being somewhere in the neighborhood of 1½ per cent.

Since the Steel Corporation has in Minnesota on the Mesabi and Vermilion range about 930,000,000 tons on the assessors' lists, it would

appear that the total valuation would be somewhere in the neighborhood of $140,000,000 and the taxation approximately $2,000,000. On this basis we find that the company must pay on its present output of approximately 18,000,000 tons, more than 10 cents per ton on its actual shipments.

This taxation is a recent development. I do not believe that the company has as yet actually paid so much, but on a basis of present and future conditions it does not seem like an excessive estimate. The fairness of this mode of taxation it is not my present purpose to discuss, but it is very evident that a company with large ore reserves and a small output may be taxed much more than a company with a large output and small ore reserves. For instance, if the Steel Corporation had only five years' ore in sight instead of 50 years, its taxes in its present tonnage would be only 1 cent per ton instead of 10 cents. For this reason there are probably vast differences in the tax rates of various companies in the Mesabi range, and I suppose the Steel Corporation undoubtedly pays more taxes per ton of output than any of the others.

Explorations and Maps.—It may be interesting to digress for a moment to consider the value of combination in the operation of these mines. Since its organization the Steel Corporation has pursued a most complete, scientific, and satisfactory plan of exploring and mapping its ore reserves. It has employed expert geologists and engineers for this purpose. It has secured as much land as it could for exploration and has explored it to the point of determining, before any mining is done, the situation, volume, shape, and economic characteristics of the orebodies on large tracts.

In other words, the process of drilling and test-pitting has been carried on until the depth of surface, the quality of the ore, its probable admixture with boulders and tongues of barren rock, and its thickness have all been determined. This information is expressed on maps which show the contours not only of the surface of the land, but also of the surface of the orebody underlying the glacial drift and the contours of the bottom of the orebody.

The information permits the planning of the mining work in such a way that there shall be no duplication of effort. The drainage of an orebody can be provided for with a single shaft so situated that it reaches the bottom of the deposit. The problem of mining is solved beforehand. In other words, the propriety of mining in open pits or underground is predetermined. The location of pits, of dumping grounds, of railroad tracks and of all equipment is established once for all.

Drawbacks of Individual Management.—Now, suppose these same orebodies were to be mined by different companies as was, or would have been, the case twenty years earlier. The orebodies are sometimes a mile or even two miles in length and quite irregular in outline. The ordinary course of the longest axis of an orebody is northwest and south-

east, so that it would cross the subdivisions of the land diagonally. Such an orebody would inevitably occur on several sections, quarter sections, or 40-acre tracts. The land ownership is scattered and irregular. It is seldom that any tract belonging to a single owner is larger than 160 acres and many tracts are only 40 acres in area. As a matter of fact most of the great orebodies on the Mesabi range belonged originally to five or six different companies.

In such a case it is evident that each company would have its individual management, its own problem of finance, and its own requu rements in the way of output. The mine located on one particular 40-acre tract might find the surface only 20 ft. deep, and it would plan an open pit. Since the neighboring ground was seldom thoroughly explored, the waste from this open pit might very likely be, and indeed was in many cases, dumped on ground afterward proved to be ore-bearing.

The next mine on the same orebody might find the surface to be locally 100 ft. deep, and if the operating company were poor and in a hurry for ore, it would undoubtedly open up its mine underground. The result of this would be that large sections of the surface would be caved down into the middle of the ore, thus preventing forever the successful stripping of that part of the orebody.

Economy of Large Ownership.—But if this whole orebody were in the possession of the Steel Corporation, its explorations might show that the surface averaged about 50 ft. and that it might be economical to mine all the ore by an open pit. A single pump shaft would be sufficient. No waste would be dumped on neighboring ore-bearing ground. In short, a vast amount of duplicated expense would be avoided. This is where the value of such a combination comes in.

The Steel Corporation cannot get its work done any cheaper than anybody else. If it has to sink a shaft, for instance, it cannot do it any cheaper than any one of the half dozen mines that it might replace, but it could on the average sink one shaft for one-sixth the expense that it would cost other people to sink six shafts.

It is worth remarking in this connection that the Steel Corporation has been magnificently managed. It has not striven for minute and near-sighted economies. It has not tried to outdo its rivals in points of local rivalry, but it has kept in mind the broad outline of its operations and has tried to make use of its capital and opportunities in ways that every fair-minded man would recognize as legitimate. The company can do this only as long as it is well managed, but up to the present it is only fair to say that its activities have been well directed and that its economies are such as to be certainly of no disadvantage to the public at large, but on the contrary in many ways a great benefit.

Total Cost of all Lake Superior Ores.—In order to keep the proportion of things in mind, even at the expense of some repetition, we may state

that the cost of mining Lake Superior iron ores is for Mesabi ores, \$0.60; old range ores, \$1.15 a ton. Since the Steel Corporation mines about 7 tons of ore on the Mesabi range for over 3 tons mined on the old ranges, we may calculate that the actual cost of 10 tons would be \$7.65 or 76½ cents. To this we must add taxes which on the Mesabi range are not far short of 10 cents per ton. In order to make a round figure we may state that all Lake Superior ores would cost on the ground about 85 cents per ton, including taxation. To this we may add 20 cents per ton for royalty, making the total cost of Lake Superior iron ores at the mine, ready for shipment, \$1.05 per ton.

Transportation of Ores.—The ores which are mined on both shores of Lake Superior, either in northern Wisconsin and Michigan or in Minnesota, must all be transported to the region lying south of the Great Lakes for smelting. The region of iron manufacture extends from the neighborhood of Chicago and Milwaukee at the northwest, eastward in a widening belt to Pittsburg and Buffalo and thence east to the neighborhood of New York City.

The factors which dictate the production of pig iron in this region are two, namely, the presence of coal and facilities for distribution. If we take Pittsburg as the most active and central point in iron manufacture to represent average conditions we find that the ores must be transported about 1000 miles in three sections: (1) There is the land haul from the mine to Lake Superior ports; (2) the lake haul from Lake Superior to Lake Erie; (3) the land haul from Lake Erie to Pittsburg.

The first division of the work is covered by five or six different roads—three in Minnesota and the remainder in Michigan and Wisconsin. The length of haul is variable; from Ely, Minn., on the Vermilion range to Two Harbors, the distance is about 90 miles. Most of the ore from the Mesabi range has to be hauled from 70 to 100 miles, so that I suppose an average distance for the north shore roads is perhaps 80 miles. Most of the ore on the Marquette range is less than 20 miles distant, while that on the Menominee range is bout 50, and from the Gogebic range the distance is only about 30 or 40 miles to the harbor.

The published rates on ore from mines in Minnesota to the lakes is uniformly 80 cents per ton; from the Gogebic range to Ashland, 40 cents; from the Menominee range to Escanaba 40 cents, and from the Marquette range to Marquette, 25 cents. In the case of any company other than the Steel Corporation it would be necessary to take these rates at their face value, but in this case there is reason to believe that the transportation is the most profitable part of the business.

The company does not own any railroads on the southern shore, but its two railroads on the northern shore, namely, the Duluth & Iron Range and the Duluth, Missabe & Northern, haul about 52 per cent.

of the ore produced in the entire region. The corporation also owns a fleet of boats on the lakes, probably sufficient to transport an equal amount. It also owns the Pittsburg, Bessemer & Lake Erie railroad, which hauls most of the ore to Pittsburg. I think we shall not be far wrong if we assume that so far as costs go the results are the same as they would be if the company transported all its own ore from the Minnesota mines to the furnaces.

While the freight on ores from the south shore to Pittsburg is undoubtedly less than that from Minnesota, it is also true that the Steel Corporation must pay on ore transported from those ranges a profit to independent railroad companies which it does not pay in the case of Minnesota ores. Its profits on Minnesota ores which it hauls for other companies probably more than counterbalance the amount it pays in profits to others on the Michigan ores.

Automatic Handling of Ore.—Iron ore is about the most easily handled material in the world. Its specific gravity is high, so that the ton does not occupy much bulk, and it is absolutely uninjured by the roughest treatment. As a matter of fact, it is loaded directly into dump cars either by the steam shovels or directly from the mine shafts. It is made up in trains of approximately 2000 tons of net freight and hauled over roads of very slight, or no adverse gradients to the lake docks. There it is dumped by gravity right into the hold of the ship and transported in large cargoes on waters that are generally tranquil, and unloaded by machinery at the lower lake ports, to be again delivered to the dump cars and carried as before to the furnaces.

I believe the operating cost of hauling such material by rail cannot exceed ¼ cent per ton per mile. On this basis transportation from the mines to Duluth would cost about 20 cents, and from Lake Erie to Pittsburg about 40 cents per ton, making a total for rail haul of 60 cents. The lake freight in all probability will cost, including unloading, an average of about 40 cents. Thus we have a total transportation cost of $1 per ton from the mines to Pittsburg. This, of course, is merely operating cost, and does not include the necessary return on the capital invested in the transportation properties, but this item I propose to consider as a lump to be added to the cost of pig iron so that I will not discuss it here.

We have, then, ore delivered at the furnaces at Pittsburg at a total cost of $2.05 per ton, distributed as follows: Mining, 85 cents; royalty, 20 cents; transportation, $1.

Cost of Coke.—Without going into details, I think it would be fair to estimate the cost of Connellsville coke to the Steel Corporation at about $1.40 per ton. This is on a basis of 70 cents per ton for mining the coal and using 1½ tons of coal per ton of coke at a coking cost of 35 cents. The freight rate from Connellsville to blast furnaces at Pittsburg is

75 cents per ton, so that we may calculate coke delivered at the furnace at $2.15.

Cost of Producing Pig Iron.—It is not probable that the average Lake Superior ore of to-day will yield much over 50 per cent. in pig iron before moisture is deducted. Since the tendency is toward a gradual reduction in the grade of the ore, it does not seem far out of the way to assume that two tons will be required for each ton of pig iron. We may now calculate, when an average output of 10,000,000 tons of pig per year is made, the cost to be as follows: Use of capital, $3.77; 2 tons of iron ore at $2.05, $4.10; 1.2 tons coke at $2.15, $2.58; limestone for flux, 50 cents; labor and maintenance at furnaces, $1.40; general expense, 25 cents; total cost at Pittsburg, $12.70; freight from Pittsburg to New York, $2.60; total cost at New York, $15.30.

An interesting commentary on the correctness of these figures is the testimony of Judge Gary in the tariff hearings before the Ways and Means Committee of the House of Representatives. Mr. Gary gives costs for the year 1906 for all the furnaces of the United States Steel Corporation. His figures are those not of actual cost, but of market prices for fron ores, coke, and transportation.

The figures are as follows: Iron ore at $4.70 per ton; cost of ore used in a ton of pig iron, $8.62; coke at furnace, $3.93 per ton; coke used in making a ton of pig iron, $4.15; limestone per ton, $1.06; limestone in pig iron, 49 cents; scrap, cinder, and scale, 27 cents; labor and maintenance at furnaces, $1.37; depreciation of furnaces, 40 cents; total cost of making a ton of pig iron, $15.30.

From these figures Mr. Gary makes the following deductions for net profits: On ores in pig iron, $2.04; on coke in pig iron, 60 cents; on transportation, $1.07; total deductions, $3.71. Subtracting this amount we have by Judge Gary's estimate $11.59 per ton as the cost of pig iron at the furnaces.

Mr. Gary's Figures in Detail

Actual cost of iron mining at all mines	$ 0.73
Actual cost of coke at ovens	1.21
Actual cost of iron ore at furnace	2.83
Actual cost of coke at furnace	3.39
Pig Iron:	
Iron ore per ton pig	5.50
Coke per ton pig	4.07
Limestone	0.49
Cinder and scale	0.27
Operating blast furnaces	1.38
	$11.71
Depreciation of blast furnace	0.40
	$12.11

There is, however, some doubt as to the exact application of the figures presented by Mr. Gary. Any one who is familiar with testimony taken at a hearing will understand why this is so. I have gone over the evidence and put together the figures in another way. I do not know which is the most accurate.

These figures omit general expenses, which, it is explained, are kept in a separate account.

It will be noted that with this explanation the sum total of Mr. Gary's figures are not far from my independent estimates. It is to be pointed out, however, that Mr. Gary's figures are for all the furnaces of the company, while mine are for Pittsburg alone. This fact will make a divergence in the details unavoidable. Furthermore, my figures are for general conditions as they are, while Mr. Gary's are exact statements for a single year. After giving the matter considerable thought I have decided to leave my estimates as originally made. They will at least serve to show something of the logic of calculating costs.

Statistical Record of the U. S. Steel Corporation.—It was stated in the foregoing that the Steel Company is as much a manufacturing as a mining concern. While the principal motive of this work is to obtain figures on the cost of mining, it will be interesting, nevertheless, to give some idea of the entire business of this company, including the data upon which the above discussion is based.

The following table gives the total production of the various products since the beginning of the company:

Products	Tenn. C. and I. not included	
	1902 to 1907 inclusive, tons	Average, tons
Iron Ore Mined:		
From Marquette range	7,806,000	1,301,000
From Menominee range	11,340,000	1,890,000
From Gogebic range	9,766,000	1,628,000
From Vermilion range	10,129,000	1,188,000
From Mesabi range	64,421,000	10,736,000
Total	103,462,000	16,743,000
Coke manufactured	66,744,000	11,124,000
Coal mined, not including that used in making coke	9,786,000	1,631,000
Limestone quarried	11,126,000	1,854,000
Blast-Furnace Products:		
Pig iron	53,767,000	8,961,000
Spiegel	789,000	131,000
Ferro-manganese and silicon	327,000	54,500
Total	54,883,000	9,146,500

TABLE—*Continued*

Steel Ingot Production:		
Bessemer ingots	41,387,000	6,894,000
Open-hearth ingots	24,536,000	4,089,000
Total	65,923,000	10,983,000
Rolled and other Finished Products for Sale:		
Steel rails	10,541,000	1,757,000
Blooms, billets, slabs, sheet, and tin plate bars	5,317,000	886,000
Plates	4,068,000	678,000
Heavy structural shapes	2,370,000	395,000
Merchant steel, skelp, hoops, bands, and cotton ties	6,006,000	1,001,000
Tubing and pipe	5,277,000	879,000
Rods	1,151,000	192,000
Wire and products of wire	7,640,000	1,273,000
Sheets—Black, galvanized, and tin plate	5,390,000	898,000
Finished structural work	3,077,000	513,000
Angle and splice bars and joints	873,000	145,000
Spikes, bolts, nuts, and rivets	344,000	57,000
Axles	840,000	140,000
Sundry iron and steel products	270,000	45,000
Total	53,164,000	8,859,000
Spelter	167,000	28,000
Copperas (sulphate of iron)	111,000	18,000
	Bbls.	I bls.
Universal Portland cement	7,611,000	1,268,000

Production.—The production of the several subsidiary properties for the year 1908, in comparison with the results for the year 1907, is shown in the subjoined table. In order to make the comparison upon relatively the same basis, the production figures of the Tennessee Coal, Iron & Railroad Company for the entire year 1907 have been included in the results shown in table on the following page for that year:

Products	1908, tons	1907, tons
Iron Ore Mined in Lake Superior Ore Region:		
Marquette range	830,087	1,170,496
Menominee range	1,021,598	1,625,358
Gogebic range	1,078,025	1,425,457
Vermilion range	927,206	1,724,217
Mesabi range	11,272,397	16,458,273
Iron Ore Mined in Southern Ore Region:		
Tennessee Coal, Iron & R. R. Co's mines	1,533,402	1,576,757
Total	16,662,715	23,980,558

Products	1908, tons	1907, tons
Coke Manufactured:		
Bee-hive ovens	7,591,062	12,716,013
By-products ovens	578,869	828,751
Total	8,169,931	13,544,764
Coal mined, not including that used in making coke	3,008,810	3,550,510
Limestone quarried	2,186,007	3,201,222
Blast-Furnace Products:		
Pig iron	6,810,831	11,234,447
Spiegel	74,716	130,554
Ferro-manganese and silicon	48,861	57,794
Total	6,934,408	11,422,795
Steel Ingot Production:		
Bessemer ingots	4,055,275	7,556,460
Open-hearth ingots	3,783,438	5,786,532
Total	7,838,713	13,342,992
Rolled and Other Finished Steel Products for Sale:		
Steel rails	1,050,389	1879,985
Blooms, billets, slabs, sheet, and tin plate bars	551,106	761,195
Plates	312,470	894,364
Heavy structural shapes	313,733	587 954
Merchant steel, skelp, hoops, bands, and cotton ties	577,591	1,338,833
Tubing and pipe	654,428	1,174,629
Rods	93,406	126,095
Wire and products of wire	1,275,785	1,481,226
Sheets—Black, galvanized, and tin plated	770,321	1,070,752
Finished structural work	403,832	719,887
Angle and splice bars and other rail joints	84,669	195,157
Spikes, bolts, nuts, and rivets	40,252	67,991
Axles	24,057	189,006
Sundry steel and iron products	54,893	77,463
Total	6,206,932	10,564,537
Spelter	28,057	31,454
Sulphate of iron	26,411	24,540
	Bbls.	Bbls.
Universal Portland cement	4,535,300	2,129,700

The corporation has been engaged from the beginning not only in managing and operating the plants with which it began, but in adding thereto and expanding its business. The table on the following page, from the report for 1908, shows the estimate put upon the increase of capital by the officers of the company.

Regarding these increases of capacity, it will be observed that no estimate is made of the increase for the property as a whole. In blast-furnace products the increase is 100 per cent.; in steel ingots over 80 per cent.; in finished products, 66⅔ per cent.; and in cement, 1100 per

Comparative Annual Productive Capacity
April 1, 1901, *and January* 1, 1909

	Capacity April 1, 1901, tons	Increase since April 1, 1901: By purchase of Union and Clairton Cos., tons	By purchase of T. C., I. & R. R. Co., tons	Due to additions and improvements made by the companies after their acquirement by U. S. Steel Corpn., tons	Capacity January 1, 1909, tons
Blast-furnace products.....	7,400,000	1,228,000	1,000,000	5,322,000	14,990,000
Steel ingots...............	9,425,000	1,258,000	500,000	5,887,000	17,070,000
Rolled and other steel and iron products for sale....	7,719,000	1,103,000	400,000	3,678,000	12,900,000
	Bbls.			Bbls.	Bbls.
Cement.................	500,000	....	....	5,600,000	6,100,000

cent. Which of these is most representative of the business of the corporation? No statement is made as to the increases in natural resources. Considering the fact that the company's business as a finality resolves itself principally into the sale of finished iron and steel products, it seems most reasonable to take the increase of capacity in that particular as representing most nearly the increase in the company's whole business.

Let us assume, therefore, that the producing capacity of the properties has been increased by two-thirds since the organization.

What this increase has cost is exhibited by the following table:

"Since the organization of the corporation there have been expended for additional property and construction (exclusive of the cost at date of acquirement of Union Steel and Clairton Steel Companies, and of the stock of Tenessee Coal, Iron and Railroad Company) the following amounts:

For account of the Gary, Indiana, Plant, including the building of the city of Gary and terminal railroad work..................	$ 42,797,229.57
For account of the manufacturing properties (including expenditures by U. S. Steel Corporation)...........................	116,155,559.41
For account of the coke and coal properties.....................	20,056,764.27
For account of the iron ore properties..........................	23,120,539.17
For account of the transportation properties....................	49,026,895.81
For account of the miscellaneous properties.....................	4,340,999.14
Total capital expenditures..................................	$255,497,987.37
During the same period there was expended for extraordinary replacements and betterments the sum of....................	92,534,952.12
Total..	$348,032,939.49

"On account of the foregoing expenditures there were issued and disposed of, bonds, mortgages, and purchase obligations of subsidiary companies to the amount of $39,172,863.37, leaving a balance of expenditure of $308,860,076.12, the funds for the payment of which have been provided from the current earnings and surplus of the organization. There have also been paid off through operation of the bond sinking funds, and by discharge upon their maturity $85,871,-019.36 of bonds, mortgages, and other capital obligations which were outstanding at the time of organization of the U. S. Steel Corporation."

The statement leaves in doubt the exact meaning of the expenditures for extraordinary replacements and betterments. It seems most probable that such expenditures should be charged off to depreciation. Making this deduction, we find that the capital expenditures have been $255,498,000 plus the cost of the Union and Clairton Steel Companies and the Tennessee Coal, Iron & Railroad Company. The sum total of which appears to be in the neighborhood of $94,000,000. A round figure for all capital expenditures since the organization we may take as $350,000,000.

On the assumption that these expenditures have increased the total productive capacity of the concern by two-thirds, it is easy to deduce the conclusion that the actual capital invested in the enterprises at the beginning of the organization was $525,000,000, and that at present the total invested capital can be calculated at $875,000,000, a sum which may be compared with the total obligation of the company in preferred stock and bonds of the corporation, which amount in par value to $958,315,000.

The cash surplus of the corporation is kept in round numbers at $50,000,000, the remainder of the surplus, which is stated to be $133,000,-000, having been expended on the various plant investments. The working capital may be safely assumed to be represented by the inventories which were, at the end of 1908, $143,180,000 plus the cash, making a total sum of $193,000,000. Adding this to the foregoing estimate of fixed capital investments, we arrive at a total of $1,068,000,000 as the actual capital employed in the enterprise. This sum plus the natural enhancement of the value of its properties is what the stockholders of the corporation have to show for their money.

Analyzing this matter a little further we find that the obligations in the preferred stock and bonded indebtedness amount to $958,000,000, so that the common stock represents the equivalent of $110,000,000 invested capital plus all of the enhancement in the value of the property—a state of affairs with which the stockholders should be satisfied.

The following table shows the disposition made of the earnings of the company since the beginning:

Net Profits and Surplus of United States Steel Corporation and Subsidiary Companies at Close of each of the Periods Named

(Includes only Surplus received or earned on or subsequent to April 1, 1901)

Period	Net profits for period available for dividends	Surplus at close of period before declaration of dividends[1]	Dividends on U. S. Steel Corporation stock for respective periods	Written off account of capital expenditures, for special funds and for sundry adjustments and accounts	Balance of surplus
Nine months ending Dec. 31,1901	$60,600,109.05	$85,600,109.05	$41,979,168.75	....	$43,620,940.30
Year ending Dec. 31,	90,306,524.25	133,927,464.55	56,052,867.50	....	77,874,597.05
QUARTER ENDING					
March 31, 1093	14,891,989.64	92,766,586.69	14,012,944.25	....	78,753,642.44
June 30, 1903	23,987,950.22	102,741,592.66	12,609,770.92	....	90,131,821.74
September 30, 1903	49,684,774.49	109,816,596.23	10,006,759.90	....	99,809,836.33
December 31, 1903	2,230,775.78	102,040,612.11	6,482,260.84	$29,461,668.91	66,096,682.36
March 31, 1904	4,606,593.70	68,099,358.51	6,304,919.25	....	61,794,439.26
June 30, 1904	9,082,563.81	69,700,504.29	6,304,919.25	....	63,395,585.04
September 30, 1904	7,617,906.85	73,831,323.75	6,304,919.25	....	67,526,404.50
December 31, 1904	10,143,836.95	77,378,489.44	6,304,919.25	9,708,124,50	61,365,445.69
March 31, 1905	12,178,326.35	71,826,602.51	6,304,919.25	3,300,000.00	62,221,683.26
June 30, 1905	16,875,599.99	82,537,094.61	6,304,919.25	7,500,000.00	68,732,175.36
September 30, 1905	16,977,532.04	90,322,263.92	6,304,919.25	6,500,000.00	77,517,344.67
December 31, 1905	22,653,287.55	100,142,623.70	6,304,919.25	9,099,253.78	84,738,340.67
March 31, 1906	22,371,919.85	102,570,244.10	8,846,321.75	10,500,000.00	83,223,812.35
June 30, 1906	24,536,025.28	110,636,708.48	8,846,431.75	13,000,000.00	88,780,176.73
September 30, 1906	23,543,749.98	118,444,038.26	8,846,431.75	11,000,000.00	98,597,606.51
December 31, 1906	27,767,393.02	124,657,647.29	8,846,431.75	18,090,501.19	97.720,714.35
March 31, 1907	27,031,008.20	118,256,429.88	8.846,431.75	14,500,000.00	94,909,998.13
June 30, 1907	30,843,512.61	131,134,185.12	8,846,431.75	18,500,000.00	103,877,753.37
September 30, 1908	28,758,142.27	140,376,218.82	8,846,431.75	15,000,000.00	116,529,787.07
December 31, 1907	18,614,416.20	138,173,190.89	8,846,431.75	6,681,515.52	122,645,243.62
March 31, 1908	8,854,297.37	127,092,583.20	8,846,431.75	....	118,246,151.45
June 30, 1908	9,042,027.55	125,937,322.46	8,846,431.75	....	117,090,890.71
September 30, 1908	13,998,455.19	137,506,368.22	8,846,431.75	....	128,659,936.47
December 31, 1908	13,739,899.00	142,167,611.33	8,846,431.75	Cr. 94,034.59	133,415,214.17

Summary—April 1, 1901, to December 31, 1908

Capital surplus provided at date of organization			$25,000,000.00
Aggregate net profits as above		$560,938,617.19	
Less, amount included therein representing accrued profits on inter-company materials on hand in inventories	$10,371,8 3.25		
Net charges against profits made at close of fiscal years, not applicable to particular quarters	7,119,665.15		
Reserved for fund to cover possible failure to realize advanced mining royalties	2,800,000.00		
		20,291,468.40	
Balance of profits earned			540,647,148.79
			$565,647,148.79

[1] Includes Capital Surplus of $25,000,000 provided at date of organization, also Undivided Surplus of Subsidiary Companies representing accrued profits on Inter-Company materials on hand in inventories.

Dividends paid on U. S. Steel Coporation Stocks, viz.:		
Preferred, 54 per cent	$218,975,274.66	
Common, 15 per cent	78,765,032.50	
		297,740,307.16
Leaving a surplus of		$267,906,841.63
Brought forward		$267,906,841.63
Of the foregoing surplus there has been appropriated for payment of construction and capital expenditures and special charges, per sixth annual report, page 8		162,827,364.16
Balance of surplus December 31, 1908, exclusive of subsidiary companies' inter-company profits in inventories		$105,079,477.47
Undivided surplus of subsidiary companies on December 31, 1908, representing profits accrued on sales of materials to other subsidiary companies and on hand in latter's inventories		28,335,736.70
Total		$133,415,214.17

It seems legitimate to make the following comments on this statement:

The actual profits were $540,647,000 derived from the sale of approximately 67,500,000 tons of finished steel products and about 12,000,000 barrels of cement. Let us figure only on the tonnage of finished iron and steel products, and there appears a profit of $8 per ton.

Of these earnings $297,740,000 has been paid in dividends or approximately $4.40 per ton. The remaining $242,000,000 has been added to plant or used to increase the cash surplus, only $25,000,000 or some 40 cents a ton being used for the latter purpose, the remainder, over $217,000,000 or $3.20 per ton, being used for the expansion of the business. Under ordinary circumstances there would be in one's mind a great doubt as to whether the sum thus expended for plant extensions should be held as an addition to capital or whether it should be written off to depreciation. But in this remarkable case there seems to be no doubt whatever that the circumstances justify the treatment of the whole amount as a true capital expenditure. It is not necessary to dwell on this point further than to point out that the expansion of the producing capacity of the concern by 66⅔ per cent. shown above is a more than sufficient justification. We are led then to believe that the profits reported by the company are really profits, namely, $8 per ton, and that this is over and above all requirements for interest on bonds and building up of sinking funds, besides depreciation. This means that the sum of nearly $70,000,000 per annum has been earned by the preferred and common stock of the corporation. The full dividends of 7 per cent. a year have been paid on the preferred stock, absorbing $219,000,000[1] in the seven and three-quarters years.

The remainder, $321,000,000, has all gone to the benefit of the com-

[1] In 1903 the preferred stock was diminished by $150,000,000 by conversion into an issue of bonds. The present preferred stock amounts to $360,281,100 on which the annual dividend is $25,215,672.

mon stock and has been used to pay dividends to the amount of $78,765,000, and the building up of equities to the amount of some $242,000,000.

It is probably true that at the beginning the commonstock represented little or nothing more than a speculative possibility. But the success of the company during the last eight years has created most substantial values for it. It must be remembered that the great constructive enterprises of the corporation have as yet yielded little return. That is for the future. If we calculate that the probabilities of the future contain nothing more than a realization on the expansion already accomplished, the earning powers of the concern seem fairly prodigious. If it has now reached a point where it can pay out as dividends the earnings on a product equal only to the average of the last eight years, without counting on any increased product, we find that the earnings available for dividends are equal to $45,000,000 a year on the common stock, approximately 9 per cent. There are only two grounds for doubting that this will be realized, namely, that the prices and costs of the future may not be the same as in the past, and that the management may deteriorate. How far these elements may weaken the position of the corporation only the future can tell. But its record to date, and especially for the past five years, makes it a conservative statement that this concern is the greatest and promises to be one of the most profitable enterprises that the world has ever seen.

IRON ORE MINES

Developed Iron Ore Mines Owned by Subsidiary Companies, December 31, 1908

IN THE LAKE SUPERIOR ORE REGION

Marquette Range	*Marquette Range* (Con't)	*Menominee Range* (Con't)
Hartford Mine.	Winthrop Mine.[1]	Hilltop Mine.[1]
Queen Mine (¾ int.).	Champion Mine.	Chapin Mine.
Section 16 Mine (¾ int.).		Aragon Mine.
Section 21 Mine (¾ int.).	*Menominee Range*	Cundy Mine.[1]
Hard Ore Mine (¾ int.).	Mansfield Mine.	Iron Ridge Mine.[1]
Hematite Mine (¾ int.).	Michigan Mine.	Pewabic Mine (½ int.).
Moore Mine.[1]	Riverton Mine.	
Stegmiller Mine.	Cuff Mine.[1]	

The foregoing part of this chapter is retained because, in spite of the fact that many of its figures are now out of date, it throws into perspective a portion of the experience of one of the most characteristic of American industrial organizations. The succeeding ten years show some results that are worth noting.

The investment of capital has gone on undiminished in all departments of the business. Since 1908 the gross profits have been

[1] Inactive at present time.

$1,108,000,000 after the payment of bond interest, war taxes, etc. Of this amount $602,925,000 has been paid in dividends, that is, about 55 per cent. The remaining 45 per cent. has been retained for investment and is employed chiefly as additional working capital, in inventory and cash, and in various constructive enterprises.

The total amount of finished steel products marketed in the decennium was 120,000,000 tons. It is worth observing that the dividends have averaged just $5 per ton, against $4.40 per ton in the preceding period. The grand total production for 17 years and 9 months life of this corporation up to the end of 1918, was 187,500,000 tons of finished steel products for sale, and the dividends $900,665,000 being $4.80 per ton.

The investment of all this capital has permitted a decided increase of output but that output has not kept pace with that of the other steel and iron producers of the country. Nevertheless the increase has been considerable rising from an average of 8,700,000 tons for the first ten years to just 12,000,000 for the succeeding ten—38 per cent. The largest output of course was during the last three years of the war, but the effect of this was hardly great enough to make much difference in the grand averages; for in two years before the war, 1912 and 1913, the output was above the average for the ten year period. We are warranted in supposing that had there been no war the regular course of industrial expansion would have brought at least a year or two of high figures. If the rate of growth is to be maintained we may expect for the coming decade an average output of 16,500,000 tons finished steel products and dividends approximating $80,000,000 a year, which would be 7 per cent. on the preferred and 10 per cent. on the common stock.

By gleaning the reports for all these years it is possible to get some additional figures which throw a good deal of light on the conduct of this business. These figures relate to the employment of capital and of labor. From the standpoint of the mining business some of the facts are clearer than they were ten years ago.

The total investment account reaches the immense sum of $1,871,-000,000 which probably represents the first cost of the properties, plus the capital investments that have been added. The latter amounts come to $800,000,000 in actual cost, although the books show only $710,000-000. The difference is due to writing off $92,000,000 during the war period on account of the "excessive cost of construction." From this we may conclude that the company tries to place its assets at a normal replacement cost.

The only means available for estimating the original cost of these properties is to assume that it corresponds to the rate of the investments made since the purchase. Those investments are a shade over 40 per cent. of the total "investment account" as published, and 38 per cent. of the amount shown on the books to have been actually spent. From

this we may assume that, in round numbers, the first cost represents 60 per cent. and the additions 40 per cent. of the present investment account. Proceeding in this way we can form an estimate of the disposition of the entire invested and working capital.

The manufacturing properties include blast furnaces, rolling mills, wire mills, tin plate mills, etc. Since 1901 the great new plant at Gary, Indiana and a considerable one at Duluth have been built in entirely. The Tennessee Coal and Iron Co., and the Union and Clairton Steel companies have been purchased outright but the figures for improvements are exclusive of these purchases. These concerns however contribute to the dizzying total of the manufacturing plants. I shall not try to specify them further than to remark that there are 145 works, 124 blast furnaces, 38 Bessemer converters and 334 open hearth furnaces. The amount expended on all these plants has been $508,000,000, from which I conclude that their original cost was about $750,000,000 and their present value about $1,250,000,000. Of this amount I suppose the 124 blast furnaces must represent pretty close to $250,000,000.

Similarly we find that the coal and coke properties have cost $92,000-000, for improvements and that their present value is estimated at $230,000,000. That this is not unreasonable is attested by the fact that there are included some 330,000 acres of the best coal land in the country, with 71 coke plants and 31 additional coal mining plants, with 22,000 bee hive ovens and 2558 by-product ovens.

The iron ore properties have been improved and developed at a capital cost of $48,000,000 indicating a total value of $120,000,000. This figure does not seem unreasonable for it includes 110 mines in the Lake Superior region and 21 in the Southern fields. These properties have shipped a maximum of 33,355,000 tons of ore in a season (1916). The capital value is therefore only $3.50 per annual ton at maximum capacity and $4.30 for their average production for ten years.

The transportation properties include 1000 miles of main-line railroad, with branches, second tracks and sidings amounting to 2400 miles or more; 1421 locomotives, over 60,000 cars, and 106 large steamers and barges on the Great Lakes and the Ocean, besides 202 river barges. On these properties no less than $127,000,000 has been spent since the incorporation, indicating a present value of $300,000,000.

Miscellaneous properties include water supply plants in the coke region, natural gas and oil property and forwarding and receiving docks for ore and coal. On these some $19,000,000 has been spent indicating a value of about $45,000,000.

If we group all these figures we may get a rough approximation of the amount both of capital and labor required for the production of pig iron. It is of course impossible to separate accurately from the information given in the annual reports, the coal, coke and transportation used

only to bring the metal to the pig-iron stage, from that required in subsequent manufacture; but certain conclusions may be drawn.

It appears that the coke required to make pig iron only is about ton for ton. From this we conclude that nearly nine-tenths of the coke produced by the corporation is used for that purpose. The steam coal is not so extensively used in making pig-iron as in later manufacturing; but some must go into it. When we recollect that out of a grand total average production of 28,400,000 tons of coal no less than 20,000,000 tons is required to make the 13,500,000 tons of coke used in the blast furnaces, we may reasonably conclude that at least three quarters of the investment in coal and coke properties should be apportioned to pig iron.

All of the iron ore investments belong to the making of pig iron.

The transportation properties are chiefly used for the assembling of raw materials. Manufactured products no doubt are also handled, but necessarily only to a minor extent; they must be shipped from the factories in all directions and must go mainly on the common carriers. Materials in process of manufacture are of course transported from plant to plant, but in general they probably go only short distances. But if it is conceded that the pig iron is transported in equal proportions with the materials used in making it we should have the following comparison.

Tonnage of ore	25,800,000	Transportation required for pig iron only.
Coal	21,300,000	
Limestone	5,000,000	
	52,100,000	
Tonnage of pig iron	13,250,000	—Required for manufacture.
Total	65,350,000	

Proportion required for pig iron only, 80 per cent. We may then charge 80 per cent. of the capital in the transportation system to the making of pig iron.

To cut the discussion short we may tabulate the distribution of capital required for making pig iron only and that required for subsequent manufacturing as follows:

	Pig iron	Manufacturing
Manufacturing plants	....	$1,000,000,000
Blast furnaces	$250,000,000	
Coal and coke	172,500,000	57,500,000
Ore properties	120,000,000	
Transportation properties	240,000,000	60,000,000
Miscellaneous	35,000,000	12,000,000
Total	$817,500,000	$1,149,500,000

But the grand total of these sums is $1,967,000,000, which has been written down to $1,871,000,000. If we distribute this shrinkage between the two groups we shall have for pig iron approximately $780,000,000, for subsequent manufacture, $1,090,000,000.

These figures are for the end of 1918. To get the average capital required for the output of the ten-year period we should go back about half way, *i.e.*, charge to the production of the period only the amount that had been finished in time to participate in making the actual output and not that which provides for an increased future output. Without going into details, we arrive by this correction to the conclusion that the actual investment required to make 13,523,000 tons a year was about $700,000,000, say $53 per annual ton.

By a similar process of reasoning we may deduce the distribution of labor. We must do some guessing, but I think the amount of it will not be sufficient to cause much doubt as to the proportion of things.

It appears that prior to 1916 the cost of operating the blast furnaces was about $1.40 per ton of pig iron. This would mean an annual expenditure for labor, power, etc., of about $19,000,000. The labor alone would be perhaps $13,000,000, and would indicate the employment of about 16,000 men. With this start we may apportion the labor.

	Pig iron	Manufacturing	Total
Mining iron ore	13,214	....	13,214
Coal and coke	16,940	5,646	22,586
Transportation	16,700	4,176	20,876
Miscellaneous	2,000	978	2,978
Blast furnaces	16,000	....	16,000
Other labor	....	145,807	145,807
	64,854	156,607	221,461

This distribution indicates that the proportion of the corporation's labor required for the production of pig iron is less than 30 per cent. of the total, while the capital employed for the same purpose is about 40 per cent. of the total.

According to these figures each employe produces about 208 tons of pig iron a year. Under the pre-war conditions, say up to the end of 1915, the average cost of this labor was less than $900, rising from $780 per year in 1909 to $925 in 1915. The cost therefore of mining, preparing and assembling raw materials and operating the blast furnaces was roughly as follows:

There are certain other charges, the amount of which is not so clearly indicated. The Corporation's facilities for assembling raw materials,

	Cost of pig iron
Labor, $850, producing 208 tons	$4.20
Other operating expenses 75 per cent. additional	3.15
Thirty per cent. of Corporation's administrative expense	0.45
Forty per cent. of taxes	0.40
Total direct operating cost	$8.10

though extensive, are not all-embracing. A large portion of the pig iron is made in the Chicago district and coke must be transported thither chiefly from the Pittsburgh region. But the principal item is the depreciation of $700,000,000 capital which is taken care of under various headings called "ordinary repairs and maintenance," "extraordinary repairs" and "depreciation." How much of these expenses is covered by the Corporation's working force and how much is done by outsiders by contract is again not clear. If the depreciation averages 6 per cent. of the cost of the properties the amount will be $42,000,000—about $3.20 per ton.

It seems safe to say that the sum total of all such expenditures must fall under $4.00 per ton, and that the complete cost of making pig iron must have been less than $12.00.

It will be observed that this grouping of figures brings us to about the same conclusion arrived at in 1909.

In the general rise of prices in late years the cost per unit of labor and supplies has remained about the same, but in dollars and cents it has risen at times quite to double the figures given above. Some details may be of interest.

In the coal and coke properties during the year 1918, 28,378 men mined, 31,748,135 tons of coal, from which they made 17,757,636 tons of coke, using for that purpose 25,393,155 tons of the coal. Presumably some 5000 to 6000 of the men were employed in burning the coke. There would be left, say, 23,000 men to mine the coal. Each man would produce some 1380 tons per year, over 4½ tons per working day. Under pre-war conditions such an output would have meant a total cost of less than 90 cents per ton; but in 1918, doubtless, at least $2.00.

In the iron ore properties, 28,332,959 tons was produced by 12,619 men; no less than 2246 tons per man, 7½ tons per man per working day. This is an extraordinary output which indicates that a large part was produced by steam shovels; also probably that for that season some of the usual development work was postponed in order to economize labor for war demands. For the ten year period the average output per man in the iron mines was 1950 tons per year, about 6⅓ tons per working day. Either of these figures indicates remarkably low costs and, incidentally, the great superiority of the mines. It will be remembered that during the years 1906–1910, the total cost in the mines of Michigan was $1.65 per ton with an output of 700 tons per man per year. If the same propor

tion holds good with the Steel Corporation's mines, its cost should have been only 60 cents a ton.

The great output per man is explained almost wholly by the ease with which ore is produced from the bonanza mines of the Mesabi Range. The following figures will be an illustration. In 1916 the entire Corporation mined 33,355,169 tons of iron ore with only 12,624 men. Of this, 13,000,000 tons came from the Hibbing district on the Mesabi Range and was produced by 1800 men—more than 7000 tons per man per year, ten times the yield obtained at the underground mines. In the Virginia district, of the Mesabi, where a number of the other steam-shovel mines of the company are found, 1400 men produced 4,250,000 tons. On the Western Mesabi similar productions are made. We may believe that in 1916, 24,000,000 tons was mined on the Mesabi by not over 4400 men—a yield of some 18 tons per man per day for all the properties on it. Deducting this production we find that 8000 men produced about 9,000,000 tons from other properties, 1125 tons per man per year.

This last figure again shows how the Steel Corporation has obtained the best mines of the Lake Superior region. Its output from the underground mines seems to be at least 50 per cent. better than the average obtained by its competitors.

CHAPTER XI

OCCURRENCE, PRODUCTION AND PROSPECTS OF COPPER

Economic classification of copper mines—Cost of producing copper from disseminated ores—From quartz-pyrite ores—From smelting ores —The copper business in 1909—The outlook in 1919—Copper minerals—World's production—Growth and distribution of production in the United States —Production of districts—Plants required—Concentration—Smelting —Refining—Dividends.

General Considerations.—We may divide copper mines into three classes, each presenting a different economical problem: (I) Disseminated ores in which concentration is the all-important thing, smelting being applied only to a fraction of the material mined. (II) Quartz pyrite ores in fissure veins in which the ratio of concentration is low, the proportion smelted considerable, making the costs usually high. (III) Ores that cannot be concentrated and must be smelted in bulk.

I. Disseminated Ores

The first class contains the Lake Superior copper ores in which native copper is disseminated, either in porphyry or in conglomerates derived from porphyries, in the proportion of from 1 to 4 per cent. These ores are concentrated in the mills (with 20 per cent. loss in milling) to from 1 to 4 per cent. of their original volume. This is the proportion smelted.

The disseminated ores are discussed in following chapters.

The salient facts regarding the cost[1] of mining disseminated ores may be expressed in the accompanying table:

Cost of Mining Disseminated Ores

		Low	High
Mining	Open pit	$0.50	
	Underground	1.25	$2.50
Concentrating		0.40	1.00
Smelting, refining, and marketing		0.15	1.30
	Open Pit	$1.05	$4.80
	Underground	1.80	

At the average price of 15 cents for copper, these figures mean that under the most favorable conditions a Lake Superior ore, if it could be mined from an open pit, might meet expenses with a yield of only 7 lb. per ton. If mined underground about 12 lb. is the minimum; while under the most unfavorable conditions a yield of 32 lb. may be required.

[1] Under the present scale of prices these cost figures are too low but the proportions are as true as ever.

Cost of Producing Copper From Disseminated Ores.—The average cost of producing the entire output of copper is hard to determine, because a respectable fraction is sold by obscure mines which may not always be profitable, and whose records are not to be had. I have taken the ground that the price must be controlled by the leading and profitable producers which sell the bulk of the output of each district. In order to form some idea of the cost to such leaders, I have compiled the following information, the justness of which will be evident to any reader.

The Calumet & Hecla Mining Company had produced up to June, 1908, approximately 2,040,000,000 lb. of copper, on which its earnings were approximately $115,000,000 net. This mine had built up its enormous plant almost entirely out of earnings, so that for its forty years of activity its real and complete cost of production must equal the selling value of its output, less the profits. The actual price received for Lake Copper in the last forty years has been almost exactly 15.3 cents per pound. Now the profit of $115,000,000 from 2,040,000,000 lb. is equal to 5.63 cents per pound. Subtract this from 15.30 cents, and we get 9.67 cents as the cost of the entire product.

Similarly, the Quincy mine has produced 413,000,000 lb. at a total cost of $45,500,000, equal to 11 cents a pound. The Copper Range mines, Baltic, Trimountain, and Champion, had produced, up to 1907, 209,000,000 lb. for $27,316,000, equal to 13.07 cents a pound. The Wolverine had produced, up to 1907, 87,000,000 lb. for $7,783,000, equal to 8.9 cents a pound.

This entire group has produced 2,740,000,000 lb. for $275,364,000, equal to a trifle over 10 cents a pound.

Looking to the future it is plain that the cost of copper from the Lake Superior district and from these same mines will exceed this figure. In some former article published in the *Engineering and Mining Journal* on this subject, I stated that the copper from disseminated, concentrating deposits could be produced for 9 cents. I was misled in making this statement by taking too narrow a view of the situation. The Calumet & Hecla in its ten most prosperous years, from 1897 to 1906, produced 855,000,000 lb. at about 8¼ cents a pound. This figure, in the light of fuller consideration, appears to be quite 1.4 cents below the average for the life of the mine to date; and still more below the prospective costs.

The situation is as follows: During the ten fat years mentioned above, the mine was in bonanza. The ore yielded quite 50 lb. per ton. Nearly all the production was from the great conglomerate ore shoot, which has been quite exceptional among Lake Superior deposits in richness. But, according to testimony given by Mr. Alexander Agassiz, the president, and by Mr. James McNaughton, the manager of the Calumet & Hecla, in the Osceola lawsuit, it appears that by 1908 the average yield of the

conglomerate had fallen to 40 lb. per ton, and the yield is steadily diminishing. The experience of the Tamarack was that the conglomerate just below the Calumet & Hecla line yielded only 20 lb. and was unprofitable. It appears probable, therefore, that the remaining ground on the conglomerate is likely to yield not more than a mean between 40 lb. and 20 lb., or 30 lb. per ton. The testimony is that between 20 and 24 million tons of conglomerate will still be produced. This means only 600 to 700 million pounds of copper. It does not seem probable that this will cost less than 11 cents on the average. This is about what it costs on the Osceola lode where worked by the same company.

When we remember that it has cost the Quincy 11 cents, that it is costing the Osceola Consolidated 12 cents, the Mohawk over 11 cents, it does not seem likely that there is any prospect of any great output below that figure. The Wolverine is indeed producing for less than 8 cents, but its output is so small as to have little effect. The Copper Range mines can hardly expect to fall under 11 cents for complete costs. Their product thus far has cost over 13 cents, but this includes the whole cost of equipment. A deduction of 2 cents a pound for the 209,000,000 lb. produced by the Copper Range mines makes over $4,000,000, which seems to be all that should be charged to the future for plant. It seems, therefore, that if the Copper Range can cover all expenses for 11 cents, it will do very well.

When we consider that these figures are for the best mines in the district, and that the factor of increasing depth increases both the cost and the danger of impoverishment, we may conclude, I think with safety, that there will be no real profits from the Lake mines under 11 cents, and very little under 12 cents. Among the Lake mines nothing had occurred up to the end of 1915 to disturb these conclusions.

Among the disseminated ores of the west it will be shown I think that during the same period experience had shown that costs were about as follows:

	Annual output, pounds	Cost per pound, cents
Miami	50,000,000	10
Chino	75,000,000	[illegible]
Ray	80,000,000	11
Moctezuma	30,000,000	[illegible]
Detroit	20,000,000	11
Nevada	70,000,000	9
Utah	200,000,000	11
Inspiration	100,000,000	9

In each case the cost is such that I believe the remainder could safely be counted on for dividends, or at least for liquid assets. The figures

strike so near to 10 cents a pound that it is hardly worth while computing an average. In fact it will be shown that the current costs in the Lake Superior district were exactly the same—10 cents.

In each case an allowance of 3 cents is probably necessary to cover the amortization of equipment before a profitable selling price is arrived at.

II. Quartz-Pyrites with Low Concentration

Of quartz-pyrite ores I have given the conspicuous examples of Butte and of the Wallaroo and Moonta. There is substantial agreement on the following points:

(1) A high mining cost owing to, *a*, high development cost due to searching for ore shoots through much barren vein material; *b*, considerable selection of ore in the process of mining; *c*, soft ground requiring elaborate timbering and filling.

(2) A high concentrating cost due in part to the use of hand sorting, but particularly to the careful milling methods required to prevent undue losses.

(3) Smelting costs are high because, first, a low degree of concentration gives a large proportion to smelt (from 25 to 50 per cent.); second, because the siliceous and aluminous character of the gangue renders smelting rather difficult; third, because the ore as mined is necessarily of fairly high grade.

The external conditions in Butte are somewhat less favorable than at the Wallaroo and Moonta, but in neither case are the high cost due to them. I believe that high costs are inherent to quartz-pyrite ores in fissure veins.

	Australia	Montana
Mining	$4.68	$3.78
Milling	1.00	4.62
Smelting, refining, and marketing	2.37	
General expenses	0.58	
	$8.63	$8.40

Applying to these costs the average price of 15 cents per pound copper, it is evident that such ores must yeild about 60 lb. copper or its equivalent in order to pay expenses. With the impoverishment of the ores with increasing depth, costs have increased, until in 1908 the average Butte copper must cost more than 11 cents and perhaps 12 cents. At the Wallaroo and Moonta copper has averaged in cost almost exactly 10 cents, and lately as high as 15 cents. The last figure, however, was an incident of the boom of 1906, and must be considered abnormal.

Other mines of this class are the Old Dominion and others on the great fault fissure of Globe, Arizona, and in part, at least, those of Can-

anea, Mexico. Whatever geological grouping may be appropriate, the economic results are similar to the illustrations given, and bear out emphatically the generalization that cupriferous pyrites with a highly siliceous and aluminous gangue, occurring in shoots in fissure veins, are essentially high-cost ores at every stage of the process.

Cost of Producing Copper at Butte.—Let us examine critically the record of the Anaconda Copper Mining Company to get some light on the past and future cost of metal at Butte. At the beginning it is well to explain that the record is only a broken one, there being no reports showing the exact condition of the company for a period of seven years, from 1898 to 1905. During this dark age there were indeed some scraps of information given out, but the output, even, has not been stated with authority. We have, however, enough information to enable one to make some fairly accurate deductions as to the past and future cost of production.

The present company was reorganized and began business July 1, 1895. It had at that time little or no surplus in its treasury. Up to April, 1908, it had paid $39,500,000 in dividends, and had accumulated a surplus of $6,261,000. It seems fair to conclude that in 12½ years the earnings were $45,500,000.

This had been obtained from an output which, as just mentioned, is not stated with authority but is approximately 1,228,000,000 lb. copper, 45,365,000 oz. silver, and 196,000 oz. gold.

The average price of metals for the period was 15 cents for copper, 57 cents for silver, and $20 for gold. It is not strictly accurate to apply these prices to the entire output, but as the output has been fairly uniform for the period there is no likelihood of inaccuracy sufficient to throw our calculation far astray.

Let us now convert the silver and gold into their equivalent in copper at 15 cents a pound. We find that

45,365,000 ounces silver at 57 cents equals	172,387,000 lb.
196,000 ounces gold at $20 equals	25,968,000 lb.
Add the copper metal	1,228,000,000 lb.
We get the total copper equivalent	1,425,455,000 lb.

By dividing the profit of $45,500,000 by 1,425,000,000 we get the average profit per pound, which is 3.19 cents. Subtract this from the average price of 15 cents, and we have the cost, which equals 11.81 cents per pound. Of course if the value of gold and silver were deducted from the cost and the remaining sum only charged against the copper, the latter would be substantially cheaper, but that does not seem logical.

Let us now leave the sphere of approximations and examine those parts of the record where exact figures are given. In the two years ending June 30, 1897, we find that the total output was as follows:

Tons dry ore	2,681,623	—
Pounds refined copper	239,400,895	$25,041,240
Ounces silver	11,249,792	7,387,965
Ounces gold	38,680	798,000
		$33,227,205

The copper equivalent is 317,660,000 lb., this being equal to 118.5 lb. per dry ton.

The total expenses for the period were $24,855,214.29 and the cost per pound for operating was therefore 7.825 cents. To this may be added a total increase of capital accounts of $967,641.70. If we write this all off to operating the cost is increased by 0.304 cents and the total becomes 8.129 cents per pound.

The total cost per ton was $9.23.

After making the reports of which the above is a summary, the company issued no reports till 1905. We have satisfactory reports for the years 1905,1906, and 1907. This period represents the progress of the company for an average of nine years. For the three final years the record was

Tons produced	4,075,725
Copper metal, lb	253,363,226
Silver, oz	8,098,139
Gold, oz	43,420
Equivalent in copper	286,136,000
Copper equilvanet per ton, lb	70.2
Total receipts	$50,089,139
Dividends paid	16,650,000
Net diminution of surplus	769,000
Actual profits	15,881,000
Net value per lb. copper, cents	17.514
Net profit per lb. copper, cents	5.553
Net cost per lb. copper, cents	11.961
Total cost per ton	$8.394

The meaning of these figures is so obvious as scarcely to require comment. We find the mines producing practically the same tonnage as nine years before. The cost per ton has diminished $1.24. The yield of ore has diminished from 118.5 lb. to 70.2 lb. per ton, in spite of the fact that the later production has been helped out a little by the re-working of slags from the earlier period. The diminution in the grade of the ore has far out-weighed the diminution of cost per ton, so that the cost of copper has risen from 8.129 cents to 11.961 cents, a net increase of 3.832 cents per pound. It is fair to remark that the costs in the latter period were adversely affected by the shortening of hours of labor, increased wages, and the general inflation of prices of a boom period; but it must be noted that these adverse conditions did not become

acute until the middle of 1906, and in any event cannot go far in accounting for the great cost increase.

I am not fully qualified to express an opinion as to how far the experience of the Anaconda represents that of other Butte mines, but all indications are that it represents them pretty accurately. We find that at the earlier period the Anaconda was producing better ores than any other mines have recently produced. Some rich ore has been found in the lower levels, below 2000 ft. in depth, but not enough to arrest the decline in metal contents for the total output. There is, of course, no reason to doubt that by careful selection of ores the decline may be temporarily overcome, but this can only be by a proportionately rapid depletion of reserves.

It seems perfectly certain that the selling cost of Butte copper in 1908 was fully 12 cents a pound and was constantly rising. The rise is not likely to be stopped by anything short of a diminution of output, which would be caused by the extensive selection of ores in order to bring them up to a higher grade. A good deal can undoubtedly be done to hold costs down. Whenever it is imperative wages can be cut. A diminished output at profitable cost is better than a large output without profit. The Anaconda mines are undoubtedly developed and worked somewhat in advance of the average of the district, because they are the oldest. How far in advance they are cannot be stated, but the logic of events to date is that in ten years more, if tonnage is maintained, this property will be no longer profitable.

III. When All Ore must be Smelted

I have given as examples of the third class of copper mines; *i.e.*, that in which all the ore must be smelted, Bisbee, Arizona, Tennessee Copper, Utah Consolidated, Granby Consolidated, and Mount Lyell. To this list might be added the Rio Tinto pyrite mines of Spain and Portugal, the mines of Shasta County, California, United Verde in Arizona, Cerro de Pasco in Peru, and others of less importance.

Economically we may make the following distinctions in this class:

(1) Cupriferous pyrites in an advanced state of alteration and reconcentration, so that only a small part of the original mass can be mined. In this case mining costs as well as smelting costs are inevitably high. Bisbee, Arizona, is a good example.

(2) Cupriferous pyrites in their original state or moderately enriched. In this case there is usually presented a large mass of homogeneous ore easily mined and easily treated. Tennessee Copper, Utah Consolidated, and Mount Lyell are examples. At these properties the cost per ton is from $4.20 to $6.

(3) Disseminated, self-fluxing ores not very pyritic. Granby Consolidated is an example.

Speaking generally, it must be admitted that mines of class III produce a goodly proportion of the world's copper. The list of big producers includes the Rio Tinto, the Copper Queen, Calumet & Arizona, United Verde, and many other mines not so big, but very profitable. Rio Tinto seems to produce the cheapest copper in the world, but I believe this is due to the fact that the sulphur is also utilized to an important extent. Leaving out this case, in which copper costs only 5 cents per pound, it does not seem probable that much copper from these ores is produced at less than 10 cents per pound.

The approximate cost of producing from some of the larger districts which produce this kind of ore is

	Pounds	Dividends	Cost, cents
Bisbee	2,500,000,000	$140,000,000	8
Jerome	1,000,000,000	50,000,000	9

These two districts are so far the most prominent of their class that it is scarcely worth while to tabulate the others. Undoubtedly these mines are the source of the cheapest copper to be had in this country.

Remarks in 1909

It is very well worth remarking that where the original pyrite masses are highly altered and the payable ores concentrated into small portions of the original orebody, rich ores have often been developed out of material which was originally too low grade to pay. This is the case of Bisbee, Arizona, and in Shasta County, California, and probably at Cerro de Pasco. Such bonanza orebodies are sure to be variable in their output and may come to a sudden end. They are exasperating to the mining engineer who tries to calculate their possibilities, and dangerous to the investor. It is seldom possible to put much ore in sight, or to count with assurance on a long life for the property. Nevertheless they are often exceedingly profitable. There is some reason to modify this. See chapter on Bisbee.

Where certain portions of the orebodies are enriched, but the original masses are still payable, the mines may exhibit painful variations in costs and profits, but still remain prospectively valuable for a long time ahead. Such cases are the Utah Consolidated, which has had a bad year, Mount Lyell, and probably the United Verde.

Where the pyrite masses are in their original condition they are apt to be uniform and reliable producers. Undoubtedly the Rio Tinto mine in Spain has a longer assured life and more stable operating conditions than any other copper mine in the world. The Tennessee Copper property is apparently the only mine of this class in America, but probably others will be developed.

The Price of Copper—Estimate in 1909.—I feel very confident that the analysis of costs demonstrates as valid the following conclusions:

1. No copper can be produced in North America under present economic conditions at a profit for less than 10 cents a pound.

2. At 11 cents a pound only half the present output can be produced.

3. At 12 cents many of the largest producers would only be getting a new dollar for an old one.

4. At 15 cents the business as a whole is prosperous and profitable only to an entirely legitimate degree.

5. As long as the demand increases as it has increased steadily for the past quarter century, it is safe to count for the next ten years on an average price of 15½ cents, which has been the approximate average for the last ten years.

Remarks on the Outlook in 1919.—The above conclusions were fairly but perhaps not wholly borne out up to the end of 1915.

Since that time the operating factors have gone up in price about 70 per cent. If 15 cents was a normal price before the war 25.5 cents should be the price now. It stands at about 18 cents. This means a comparative depression in the market. I believe however that if industry throughout the world were as unhampered and prosperous as it was before the war the price actually would under present cost factors average 25 or 26 cents. But we may have to wait a long time for that. The great producing power of the Americans can be absorbed only by a brisk demand from all sources. Europe can buy only what she can sell. With her working capital and raw materials depleted, her labor supply decimated, her morale dissipated, it can scarcely be anything but a slow process to regain her economic vigor. Europe has always taken about half, or more than half, of American copper. (See chapter on Gold, Wars and Prices.)

While it is no part of the plan of this volume to discuss in detail the geological or mineralogical occurrence of ores, convenience seems to demand for the reader some general statement that will show where copper comes from and how it is obtained. Some reference to geological

		Per cent. copper
Cupriferous pyrite		0.5 to 4
Richer copper sulphides—	Chalcopyrite	34.4
	Bornite	55.5
	Chalcocite	79.7
Oxides and carbonates—	Red oxide	88.8
	Black oxide	79.8
	Azurite	55.2
	Malachite	57.4
	Silicate—Chrysacolla	36.1
	Native copper	100

conditions will be found in following chapters illustrating the economic problems encountered at the various mines; so that no further description will be attempted here. The entire output of the mines to be discussed here is derived from the minerals listed above.

These various ores are apt to be found derived from an original mineralization of cupriferous pyrite which is simply iron sulphide containing a small proportion of copper. The effects of the circulation of surface waters on such ores has resulted in an extensive and often profound rearrangement of the minerals. In general terms this is the origin of most commercially valuable copper deposits. There are, however, some very important exceptions. The native copper ores of Lake Superior have not been proved to have any connection with any original sulphide. The new porphyry deposits of Utah, Nevada, Arizona, and Mexico have no defined connection with solid masses of pyrite, although they are frequently secondary sulphides. Except in the case of cupriferous pyrite, which sometimes occurs in very large homogenous masses with little admixture of foreign substances, commercial copper is invariably a mixture of the true ore with a large proportion of country rock or other minerals, technically known as "gangue."

World's Production.—The total production of copper in the world was 1,395,160 metric tons in 1918; in 1917 the production was 1,435,721 metric tons and in 1916 it was about 1,408,280 metric tons. In 1918 the copper output of the United States was 60.8 per cent. of the world's total production, in 1917 it was 60.3 per cent., and in 1916 it was about 62.6 per cent.

If we add the production of Canada and Mexico, where the mines have almost invariably some connection with those in the United States, we get the total output of North America; which was, for 1917, 67.1 per cent., and in 1918, 70.0 per cent., of the world's product.

World's Production of Copper (*a*)

Year	Metric tons	Short tons	Year	Metric tons	Short tons	Year	Metric tons	Short tons
1885	229,315	252,828	1897	412,818	455,147	1908	758,065	835,623
1886	220,669	243,295	1898	441,282	486,529	1909	854,758	942,408
1887	226,492	249,716	1899	476,194	525,021	1910	877,494	966,998
1888	262,285	281,179	1900	491,435	541,561	1911	879,751	969,750
1889	265,516	292,741	1901	529,508	583,517	1912	1,011,312	1,114,769
1890	274,065	302,166	1902	542,606	597,951	1913	1,002,284	1,104,517
1891	280,138	308,862	1903	630,590	694,910	1914	934,888	1,018,395
1892	309,113	340,808	1904	693,240	764,758	1915	1,094,803	1,206,793
1893	310,704	342,562	1905	698,931	770,221	1916	1,408,280	1,552,347
1894	330,075	363,920	1906	715,510	788,492	1917	1,435,721	1,582,595
1895	339,994	374,856	1907	724,120	798,205	1918	1,395,160	1,537,884
1896	384,493	423,917						

(*a*) The statistics for 1885–1891 are as reported by Henry R. Merton & Co.; 1892–1918 as per Mineral Industry.

THE WORLD'S COPPER PRODUCTION (FROM MINERAL INDUSTRY)
(In Metric Tons)

Country	1910 (*h*)	1911	1912	1913	1914	1915	1916	1917	1918
Africa (*a*) Cape Co.	7,016 (Cape Co. and Namaqua)	17,252	16,630 (Cape Co. and Namaqua)	5,812	3,125	*d*27,327 (Cape Co., Namaqua and Other)			
Africa (*a*) Namaqua				2,540	2,328		(*d*)34,572	45,138	31,110
Africa (*a*) Other	8,433	....	....	17,059	18,682				
Argentina (*a*)	305	1,036	335	117					
Australasia (*a*)	40,962	42,512	47,774	47,326	37,590	32,512	(*d*)35,000	(*d*)38,100	33,838
Austria-Hungary (*a*)	2,276	2,566	4,024	4,135	3,310				
Bolivia (*a*)	2,540	(*d*)2,950	(*d*)4,681	3,658	2,743	*3,000	*4,000	*4,000	*4,000
Canada (*d*)	23,810	25,570	34,213	34,587	34,027	47,202	47,985	50,626	52,693
Chile (*d*)	38,346	33,088	39,204	40,195	40,876	(*f*)52,081	(*f*)71,430	83,100	85,850
Cuba (*d*)	3,538	3,753	4,393	3,517	6,251	8,836	7,816	10,313	12,337
Germany—total (*a*)	25,105	22,363	24,304	25,309	30,480	*35,000	*45,000	*45,000	*40,000
Italy (*a*)	3,272	2,642	2,337	1,626	2,410	(*f*)1,840	(*f*)1,867	(*f*)1,331	
Japan (*f*)	50,703	*d*)52,303	(*d*)62,486	(*a*)73,152	68,058	75,415	81,280	111,256	95,800
Mexico—total (*d*)	62,504	61,884	73,617	52,815	36,337	30,969	55,128	47,503	75,529
(Boleo) (*a*)	(13,003)	....	....	(13,020)					
Newfoundland (*a*)	1,097	1,174	549						
Norway (*a*)	10,592	9,576	11,156	11,796	*11,000	*11,000	*6,000		
Peru (*e*)	27,375	28,500	(*f*)26,483	(*d*)25,715	23,647	(*d*)32,410	(*f*)41,625	45,620	44,800
Russia (*c*)	22,670	25,747	33,550	42,970	31,938	(*d*)25,881	(*d*)20,877	*16,000	*5,000
Spain-Portugal (*a*)	51,080	51,748	59,876	54,696	37,099	*46,200	*42,000	*42,000	*41,000
Rio Tinto (*a*)	(34,114)	(35,100)	....	36,901	21,515				
Tharsis (*a*)	(3,551)	(3,450)	....	3,270					
Mason & Barry (*a*)	(3,003)	(2,972)	....	3,185					
Sevilla (*a*)	(1,656)	(1,558)	....	1,535					
Sweden (*c*)	2,032	2,032	3,957	6,891	4,692	4,561	3,181	4,423	
Turkey (*a*)	610	1,016	508	508					
United Kingdom (*f*)	508	405	405	305	347	238	282		
United States (*d*)	492,720	491,634	563,260	557,387	525,529	646,212	881,237	872,065	848,203
Total	877,494	879,751	1,011,312	1,002,284	934,888	1,094,803	1,408,280	(*i*)1,435,721	(*i*)1,395,100

(*a*) As reported by Henry R. Merton & Co., Ltd., of London until 1914. (*c*) As officially reported, except for 1909, for which year the figure of Henry R. Merton & Co. is used. (*d*) As reported by the *Eng. Min. Jour.* (*e*) As officially reported 1910–1917, as per Henry R. Merton & Co., 1909. (*f*) As officially reported. (*h*) Henry R. Merton & Co., through *Eng. Min. Jour.* (*i*) Includes 25,000 tons estimated production of other countries.
* Estimated.

The following table shows the growth of the American copper industry from its beginning to the end of 1918:

MAGNITUDE AND GROWTH OF COPPER PRODUCTION IN THE UNITED STATES FROM 1845 TO 1918, INCLUSIVE

Year	Production	Increase		Average annual increase by decades	
	Pounds	Pounds	Per cent.	Pounds	Per cent.
1845	224,000				
1846	336,000	112,000	50.0		
1847	672,000	336,000	100.0	242,400	50.0
1848	1,122,000	450,000	67.0		
1849	1,568,000	426,000	40.0		
1850	1,456,000	(*a*)112,000	(*a*)7.1		
1851	2,016,000	560,000	23.1		
1852	2,464,000	448,000	22.2		
1853	4,480,000	2,016,000	81.8		
1854	4,990,000	510,000	12.5		
1855	6,720,000	1,730,000	33.3	1,467,200	28.5
1856	8,960,000	2,240,000	33.3		
1857	10,752,000	1,792,000	20.0		
1858	12,320,000	1,568,000	14.6		
1859	14,112,000	1,792,000	14.5		
1860	16,128,000	2,016,000	14.3		
1861	16,800,000	672,000	4.1		
1862	21,160,000	4,360,000	20.0		
1863	19,040,000	(*a*)2,120,000	(*a*)5.5		
1864	17,920,000	(*a*)1,120,000	(*a*)5.9		
1865	19,040,000	1,120,000	6.3	1,209,600	6.2
1866	19,936,000	896,000	4.7		
1867	22,400,000	2,464,000	12.3		
1868	25,984,000	3,584,000	16.0		
1869	28,000,000	2,016,000	7.7		
1870	28,224,000	224,000	1.0		
1871	29,120,000	896,000	3.2		
1872	28,000,000	(*a*)1,120,000	(*a*)3.8		
1873	34,720,000	6,720,000	24.0		
1874	39,200,000	4,480,000	12.9		
1875	40,320,000	1,120,000	2.9		
1876	42,560,000	2,240,000	5.6	3,225,600	8.2
1877	47,040,000	4,480,000	10.5		
1878	48,160,000	1,120,000	2.4		
1879	51,520,000	3,360,000	7.0		
1880	60,480,000	8,960,000	17.4		
1881	71,680,000	11,200,000	18.6		
1882	90,646,232	8,966,232	12.5		
1883	115,526,053	24,886,221	27.4		
1884	144,946,653	29,420,600	25.5		
1885	165,875,766	20,929,113	14.4		
1886	156,735,381	(*a*)9,140,385	(*a*)5.5	18,930,349	14.8
1887	180,920,524	24,185,143	15.4		
1888	226,361,466	45,440,942	25.1		
1889	226,775,962	414,496	0.2		
1890	259,763,092	32,987,130	14.5		

MAGNITUDE AND GROWTH OF COPPER PRODUCTION IN THE UNITED STATES FROM 1845 TO 1918, INCLUSIVE—*Continued*

Year	Production	Increase		Average annual increase by decades	
	Pounds	Pounds	Per cent.	Pounds	Per cent.
1891	284,121,764	24,358,672	9.4	34,635,407	9.4
1892	344,998,679	60,876,915	21.5		
1893	329,354,398	(*a*)15,644,281	(*a*)4.5		
1894	354,188,374	24,833,976	7.5		
1895	380,613,404	26,425,030	7.4		
1896	460,061,430	79,448,026	20.9		
1897	494,078,274	34,016,844	7.4		
1898	526,512,987	32,434,713	6.6		
1899	568,666,921	42,153,934	8.0		
1900	606,117,166	37,450,245	6.6	47,404,234	6.1
1901	602,072,519	(*a*)4,044,647	(*a*)0.7		
1902	659,508,644	57,436,125	9.5		
1903	698,044,517	38,535,873	5.8		
1904	812,537,267	114,492,750	16.4		
1905	888,784,267	76,247,000	10.6		
1906	917,805,682	29,021,415	3.3		
1907	868,996,491	(*a*)48,809,191	(*a*)5.3		
1908	942,570,721	73,574,230	8.4		
1909	1,092,951,624	150,380,903	16.0	91,046,761	6.9
1910	1,080,159,509	(*a*)12,792,115	(*a*) 1.2		
1911	1,097,232,749	17,073,240	1.6		
1912	1,243,268,720	146,035,971	13.3		
1913	1,224,484,098	(*a*)18,784,622	(*a*) 1.5		
1914	1,150,137,192	(*a*)74,346,906	(*a*) 6.1		
1915	1,388,009,527	237,872,335	20.7		
1916	1,927,850,548	539,841,021	28.0		
1917	1,886,120,721	(*a*)41,729,827	(*a*) 2.2		
1918	1,908,533,595	22,412,874	1.2		

(*a*) Decrease.

SUMMARY

Years	Total production, pounds	Average annual increase	
		Quantity, pounds	Per cent.
1845–1918	27,106,589,103	24,808,750	12.2
1845–1881 (First half)	799,624,000	2,034,333	17.2
1882–1918 (Second half)	26,306,965,103	43,895,108	8.5

The copper production of the various states of the United States for the past six years is given in the following table.

SMELTERS' PRODUCTION OF COPPER IN THE UNITED STATES[1]
(In Pounds)

State	1913	1914	1915	1916	1917	1918
Alaska	24,452,000	24,288,000	72,621,844	115,933,315	92,094,023	59,326,000
Arizona	399,849,745	387,978,852	444,089,147	692,630,286	704,156,391	765,744,496
California	32,390,272	29,515,488	37,935,893	51,358,334	46,824,320	57,576,860
Colorado	7,670,090	10,104,579	8,126,000	9,802,183	11,894,900	4,596,200
Idaho	8,434,028	4,856,460	5,602,000	6,741,001	6,401,988	5,068,500
Michigan	159,437,262	157,089,795	241,123,404	270,058,601	274,936,224	216,759,810
Montana	285,336,153	243,139,737	268,027,557	351,995,058	277,362,886	324,970,44[illegible]
Nevada	84,683,961	60,078,095	66,394,906	100,143,341	115,436,671	86,361,023
New Mexico	46,953,414	64,338,892	75,515,138	83,013,805	110,020,997	91,462,362
Utah	147,591,955	153,555,902	180,951,174	225,396,808	244,443,071	230,019,737
Washington	(*a*)	(*a*)	(*a*)	(*a*)	2,152,560	2,189,030
Wyoming	448,805	165,023	1,020,926	(*a*)	(*a*)	(*a*)
Southern States	24,333,014	19,213,965	18,858,677	20,018,261	18,704,304	16,630,377
Other States	4,155,135	4,257,088	3,431,494	15,685,226	18,127,568	9,264,845
Total	1,225,735,834	1,158,381,876	1,423,698,160	1,942,776,309	1,922,555,903	1,869,949,686

(*a*) Included in "Other States."

MINE PRODUCTION OF COPPER IN THE PRINCIPAL DISTRICTS IN 1916, IN POUNDS

District or region	State	Mine output	Percentage of total production	Rank
Butte	Montana	349,500,000	17.42	1
Lake Superior	Michigan	269,794,000	13.45	2
Bingham	Utah	223,619,000	11.15	3
Globe-Miami	Arizona	220,000,000	10.97	4
Bisbee	do	193,696,000	9.66	5
Copper River	Alaska	105,600,000	5.26	6
Jerome	Arizona	102,000,000	5.09	7
Ely	Nevada	93,044,000	4.64	8
Ray (Mineral Creek)	Arizona	76,700,000	3.82	9
Morenci-Metcalf	do	75,900,000	3.78	10
Santa Rita (Central)	New Mexico	74,228,000	3.71	11
Shasta County	California	39,700,000	1.98	12
Ducktown	Tennessee	14,556,000	0.73	13
Prince William Sound	Alaska	10,660,000	0.53	14
Pioneer	Arizona	9,145,000	0.46	15
Burro Mountain	New Mexico	9,392,000	0.42	16
Tintic	Utah	7,085,000	0.35	17
Pima	Arizona	6,683,000	0.33	18
Foothills Belt	California	6,460,000	0.32	19
Cochise	Arizona	6,204,000	0.31	20
Alder Creek	Idaho	5,499,000	0.27	21
Plumas	California	5,150,000	0.26	22
Banner	Arizona	5,041,000	0.25	23
Lordsburg	New Mexico	4,755,000	0.24	24
Planet	Arizona	3,929,000	0.20	25
Big Bug	do	3,612,000	0.18	26
Ketchikan	Alaska	3,526,000	0.18	27
Courtland (Turquoise)	Arizona	3,250,000	0.16	28
Ophir	Utah	2,702,000	0.13	29
San Juan-Ouray region	Colorado	2,640,000	0.13	30
Leadville	do	2,620,000	0.13	31
Santa Fe	Nevada	2,547,000	0.13	32
Coeur d'Alene region	Idaho	2,200,000	0.11	33
New Placer	New Mexico	2,153,000	0.11	34
Oro Grande	do	2,077,000	0.10	35
Helvetia	Arizona	1,958,000	0.10	36
Peck	do	1,618,000	0.08	37
Trinity	California	1,575,000	0.08	38
San Bernardino	do	1,525,000	0.08	39
Patagonia	Arizona	1,244,000	0.06	40
Copper Basin	do	1,225,000	0.06	41
Goldfield	Nevada	1,165,000	0.06	42
Uinta-Summit (Park City)	Utah	1,163,000	0.06	43
Bentley	Arizona	1,064,000	0.05	44
Railroad	Nevada	1,012,000	0.05	45
		1,958,216,000	....	....
All others	....	47,659,000	....	....
Grand total	....	2,005,875,000	....	....

An interesting view of the broad features of the copper mining business may be had from the following table, which shows that of all the ores treated in the United States in 1916 one-ninth are smelted direct and eight-ninths concentrated. The concentrated ores are reduced to 8.7 per cent. of their original volume before smelting. Adding this to the amount smelted crude we find the total percentage smelted to be 17.5 per cent. The average copper yield of all ores mined was 34.0 lb. per ton or 1.70 per cent. The yield from ores smelted direct was 94.4 lb. per ton or 4.72 per cent. The yield per ton of concentrating ore was 25.6 lb. per ton or 1.28 per cent.; while the resulting concentrates yielded 298 lb. per ton or 14.9 per cent.

A rough estimate of the plants required to perform the processes indicated is as follows:

Mining, milling, and smelting plants with transportation facilities between mines, mills, and smelters, at \$4.50 per ton of annual capacity for 50,000,000 tons of concentrating ore	\$225,000,000
Mining and smelting plants for 6,500,000 tons smelting ore at \$7 per ton of annual capacity	\$ 45,000,000
Total plant required	\$270,000,000

This estimate was intended to cover only such transportation lines as are owned by mining companies, not the longer lines owned by railroad companies that are used to carry ores, concentrates, matte, or bullion for great distances.

The various refineries will perhaps bring up the capital in plants by an additional \$50,000,000, making a total plant employed in the copper-mining business of at least \$320,000,000. Thisestima te refers only to the successful and active plants. The addition of failures and discarded plants would undoubtedly show a largely increased figure. Computing the future life or the average mine at fifteen years, the amortization of capital is 10 per cent. To this we must add 6 per cent. for annual depreciation, so that a total charge of 16 per cent. must be made for the use of capital. On \$320,000,000 this annual charge is \$51,200,000, or nearly 3 cents a pound on the output of 1917.

Under the conditions of 1919 this estimate would have to be increased 70 per cent. Of course, with the expansion of the business accomplished in 10 years the total figures would be much higher.

It may occur to many readers that in the following chapters undue prominence is given to copper as compared with other mineral products. It will be found however that the copper mines are a convenient starting point for the discussion of all sulphide mines, and that includes almost all metal mines except iron.

That copper mining and smelting is not an unimportant business is shown by the fact that up to January 1st, 1919 a list of 58 copper mining companies, certainly not a complete list, have paid \$1,178,000,000 in

Copper Ores Concentrated and Smelted and Copper Produced From Each Class of Ore in the United States in 1916

State	Ore concentrated				Ore smelted		
	Quantity, short tons	Concentrates produced, short tons	Copper in concentrates, pounds	Percentage of copper from ore	Quantity, short tons	Copper produced, pounds	Percentage of copper from ore
Alaska	407,520	51,353	38,977,410	4.78	209,744	80,877,429	19.28
Arizona	12,790,255	812,872	335,522,300	1.31	3,701,716	384,180,489	5.19
California	214,793	16,246	5,971,595	1.39	718,929	49,821,007	3.47
Colorado	....	....	....	......	34,429	2,977,285	4.32
Georgia	....	....	....	......	31,043	803,699	1.31
Idaho	37,141	1,665	643,042	0.87	75,909	5,924,652	3.90
Michigan	12,364,114	218,489	273,692,525	1.08	....	....	......
Missouri	....	....	....	......	124	18,200	7.34
Montana	5,610,477	1,929,232	290,282,734	2.59	587,501	52,382,319	4.46
Nevada	3,975,254	531,573	88,234,979	1.11	171,702	16,364,531	4.77
New Mexico	3,349,366	280,434	80,193,232	1.19	103,544	7,400,263	3.07
North Carolina	....	....	....	......	165	9,800	3.00
Oregon	....	....	....	......	35,409	3,580,496	5.05
Pennsylvania, Maryland, and Virginia	200,950	8,844	793,096	0.19	3,580	544,484	7.60
Tennessee	....	....	....	......	482,495	14,679,794	1.52
Texas	....	....	....	......	2,081	99,569	2.40
Utah	11,943,472	559,840	199,997,786	0.84	732,680	29,962,228	2.04
Vermont	3,361	870	125,058	1.86	1,318	148,372	5.63
Washington	38,652	3,221	670,723	0.87	29,578	1,913,507	3.22
Wyoming	....	....	....	......	6,063	2,610,622	21.53
Total and average	50,935,355	4,414,639	1,315,104,480	1.28	6,928,010	654,298,746	4.72

dividends. A few of these concerns are in Canada and South America, but their aggregate dividends are certainly less than those of U. S. mines that are omitted—a good deal less. The total output of copper credited to the United States is some 27 billion pounds. It is safe to say that the dividends in normal times have averaged about 4 cents per pound. The total profits compared to those in the iron business might seem to be small, but it must be remembered that none of the profits of the copper business come from manufacturing as is the case with most of the prominent steel companies.

COPPER DERIVED FROM ORE CLASSED AS COPPER BEARING (COPPER, COPPER-LEAD, COPPER-ZINC ORES), AND TOTAL PRODUCTION OF COPPER FROM ALL SOURCES IN THE UNITED STATES IN 1916

State	Ore treated, short tons	Copper recovered, pounds	Percentage of copper	Copper from all sources including old slags, smelter cleanings, and precipitates, pounds
Alaska	617,264	119,854,839	9.70	119,854,839
Arizona [a]	16,515,151	720,572,546	2.18	712,833,169
California	933,722	55,792,602	2.97	55,897,118
Colorado [b]	37,558	3,276,524	4.36	8,624,081
Georgia	31,043	803,699	1.30	803,699
Idaho	113,072	6,585,197	2.91	8,478,281
Michigan	12,364,114	273,692,525	1.08	273,692,525
Missouri	124	18,200	7.34	[c] 386,200
Montana [d]	6,238,087	348,978,298	2.80	352,928,373
Nevada	4,149,802	104,799,723	1.27	105,116,813
New Mexico [e]	3,453,971	87,701,873	1.27	92,747,289
North Carolina	165	9,800	3.00	9,800
Oregon	35,409	3,580,496	5.05	3,581,886
Pennsylvania, Maryland, and Virginia	204,530	1,337,580	0.32	1,337,580
Tennessee	482,495	14,679,794	1.52	14,679,794
Texas	2,081	99,569	2.40	99,569
Utah	12,685,797	230,519,968	0.92	240,275,222
Vermont	4,679	273,430	2.92	273,430
Washington	68,230	2,584,230	1.89	2,645,022
Wyoming	6,063	2,610,622	21.53	2,610,622
Total and average	57,953,357	1,977,771,515	1.70	2,005,875,312

[a] Considerable copper was recovered from old slags and ores not classed as copper ores.

[b] Most of the copper from Colorado is derived from ores classed as siliceous ores and lead ores.

[c] Mainly recovered in dressing lead ores.

[d] Considerable copper was recovered as precipitates from mine waters and from ores not classed as copper ores.

[e] A large quantity of copper was derived from ores classed as lead ores, lead-zinc ores, and siliceous ores.

CHAPTER XII

THE SOUTHWEST COPPER FIELD

AREA AND IMPORTANCE—CLIMATE—GEOGRAPHY—THE PLATEAU REGION—MOUNTAIN REGION—DESERT REGION—TALUS SLOPES AND RESERVOIRS—TRANSPORTATION —POPULATION AND ETHNOLOGY.

The greatest copper-producing region of the world may be described as a rough oval of about 40,000 square miles, measuring about 330 miles north and south and 165 miles east and west. Its most easterly extremity is at the Chino mine, near Santa Rita, New Mexico; its most westerly, at Ajo, Ariz.; its most northerly point is Jerome, Ariz., and its most southerly, Nacozari, Mexico. In New Mexico are the districts of Santa Rita and Burro Mountains; in Old Mexico, those of Nacozari and Cananea; in Arizona, those of Bisbee, Ray, Globe, Clifton, Jerome, Ajo, and a number of smaller ones. Thus, much the greater part of the field lies in Arizona, and, as nearly as may be estimated, this area produced 27 per cent. of the world's output of copper in 1917, 36 per cent. of the production of the two Americas, and an amount equal to 47 per cent. of that of the United States. Its actual production is shown in the table on the following page.

The tables do not give an exact comparison of the field under discussion with the other subdivisions of the world, because the whole of Mexico is included, and only a part of that country may properly be considered to be in this field. It is rarely possible for such data to be accurate in all respects; but, with the above explanation, the figures will serve their purpose. They are compiled from statistics published in the *Engineering and Mining Journal*, Jan. 12, 1918.

This vast copper region deserves more than a passing description. Geographically it bears considerable resemblance to Spain and Morocco, corresponding fairly well to those countries in latitude and with regard to bordering ocean; and, therefore, to a large extent in climate and physical appearance. The central part is in latitude 32° N. and is about 180 miles from the Gulf of California. The region is arid to semi-arid, the rainfall varying from 6 to 8 in. annually at Ajo to 16 or 18 in. at Globe. The climate naturally varies according to differences of altitude, the local topography, which influences rainfall and winds, and, to a minor extent, to difference of latitude. The altitude is from 2000 ft. at Ajo to 6000 ft. at Cananea. A rough average of the whole may be found at Cochise, situated in latitude 32° N. at an elevation of 4250 ft. Here

the mean temperature for the year 1916 was 60.5° F., with a maximum of 102° in July and a minimum of 6° in December. The normal precipitation is 11.78 in., but it probably varies in different years between 8 and 16 inches.

The latitude is sub-tropical, and, of course, the district is decidedly warmer than that of the more populous parts of the country; but popular fancy exaggerates the difference. Even Yuma, which is outside this area, practically at sea level, near the mouth of the Colorado River, and celebrated as the "hottest place in the world," or something to that effect, has not even an average tropical heat. The mean for 1916 was only 69.2°, the temperature varying between 110° and 20°. The hottest month, August, had a mean of 86.5°. At the Prescott Dry Farm, at an elevation of 5008 ft., the temperature varied in 1916 between 95° and 7°. At Phœnix, elevation 1108 ft., the extremes were 111° in June and 24° in December, indicating, as compared with Prescott, a difference in the extremes of temperature of about 16° for 3900 ft. of elevation.

TABLE OF COPPER OUTPUT IN POUNDS

State	1914	1915	1916	1917
Arizona	387,978,000	444,089,000	692,630,000	692,924,000
New Mexico	64,339,000	75,515,000	83,013,000	101,952,000
Old Mexico	80,000,000	67,000,000	112,000,000	90,000,000
Totals	532,317,000	586,604,000	887,643,000	884,876,000
Total United States	1,158,582,000	1,423,698,000	1,942,776,000	1,888,396,000
Total Western Hemisphere	1,479,800,000	1,797,959,000	2,429,749,000	2,392,144,000
Total world	2,050,000,000	2,388,540,000	3,099,602,000	3,114,475,000

PERCENTAGE PRODUCED BY ARIZONA, NEW MEXICO AND OLD MEXICO

	1914	1915	1917	1917
Of the United States	45	41	45.7	47.0
Of the Western Hemisphere	36	33	36.5	36.2
Of the world	26	26	28.6	27.8

PERCENTAGE OF WORLD OUTPUT PRODUCED IN WESTERN HEMISPHERE

1914	1915	1916	1917
72.2	75.2	78.4	77

The rainfall comes regularly in two rainy seasons: a winter season, culminating usually in January or February; and a summer season, in July and August. There are usually about five months, in each of which the precipitation is one inch or over; in the other seven months the fall is scant. Thus, at Cochise in 1916 the total for the year was 14.69 in., of which 12.99 in., or 89 per cent., fell in the five months of January,

July, August, September and October, the other seven months having only 1.70 in. or 11 per cent.

The record of climatic observations at Cochise is given in the twenty-seventh annual report of the agricultural experiment station of the University of Arizona, for 1916, and is shown in the table.

F. L. Ransome, certainly one of the most brilliant of geological writers, has followed the classic example of Cæsar with regard to Gaul by dividing Arizona into three parts—the plateau region, the mountain region, and the desert region. Though the boundaries are in places somewhat indistinct, in general the division is an apt and a true one.

The mines are practically all in the central or mountain belt; but since the conditions of life, in these days of swift and improving transportation, are influenced by the region as a whole, as well as by the immediate local surroundings of the inhabitants, it is not inappropriate to take note of the climate and aspect of the three belts. One cannot but be impressed

Temperature and Precipitation—Southwest Copper Field

Month	Temperature, degrees			Precipitation, inches
	Maximum	Minimum	Mean	
January	71	14	45.2	2.20
February	80	18	51.0	0.48
March	86	28	56.3	0.63
April	89	29	58.6	0.08
May	95	37	64.6	0.28
June	101	42	76.2	0.00
July	102	58	78.0	3.78
August	97	56	75.2	4.10
September	91	43	70.8	1.55
October	86	32	60.7	1.36
November	85	22	49.5	0.00
December	74	6	40.1	0.23
Year	102	6	60.5	14.69
Normal	....	....	....	11.78

by the variety of scenes, and perhaps surprised at the inaccuracies of his geography. That was my experience. Having traveled extensively in the United States, sometimes upward of 40,000 miles a year I had fallen into the conceit of assuming that I knew the country. Travel had become a bore, and I had even come to feel interested only when I could get off the train; and I looked out of the windows solely because there was nothing else to do. Probably many like myself get into a rut of preoccupation and fail in a similar way to get satisfaction out of their opportunity, or through the necessity of travel. To find a place interesting is to be interested. Many mining men are of broad intelligence, able

to take a big place in the world's affairs, as Mr. Hoover has, but I think there are many who see little in a mining country except the mines.

There is also a good deal of literature published by fanciful persons who make their product a caricature of local color. From such "authorities" one gains impressions that the unusual is the usual. To quote my own experience once more, I had gained the impression, somehow, that Arizona was a monotonous expanse of dusty desert, sparsely covered with greasewood and grotesque cacti, relieved only by an occasional sandy wash where there would be streams if there were any water, and by lonely bare mountains well scorched by the sun. There are such stretches in Arizona, but they serve only to help give the state some of its variety and interest.

Northern Arizona Plateau Land.—The great Coconino plateau of northern Arizona is said to contain the largest reserve of uncut pine timber in the United States. Above it rise the San Francisco peaks, volcanoes recently extinct, nearly 13,000 ft. high and nearly always covered with snow. Flagstaff, a lumbering town at their base, at an altitude of 6900 ft., has a climate like Minnesota. The mean average temperature is only 44°. Its precipitation is greater than that of any place along the California coast south of San Francisco; greater, I believe, than at San Francisco. Government records, not mere rumors, show temperatures as low as 25° below zero, such as are not felt in New York once in a lifetime. This plateau is not a small part of the region, but a very large part, lying immediately north of the mining districts. The U. S. Geological Survey (Guidebooks of the Western United States, Santa Fé Route, Bull. 613, a most interesting and instructive volume, by the way) has this to say:

From Isleta, an Indian pueblo on the Rio Grande, which flows into the Gulf of Mexico, the railway begins its long journey across the interesting plateau country, which, with its bordering areas, extends almost to the Colorado River, which flows into the Pacific. This vast area of high, nearly level country lies between the rugged and generally higher ranges of the Rocky Mountains on the north and the alternating short ranges and deserts of the lower-lying north end of the Mexican plateau to the south.

This is a land of varied landscapes, rocks and people. In places the plains and cliffs are vividly colored by natural pigments of red and vermilion. The rocks of the plateau are surmounted by two large volcanic piles, which stand far above the general level of the plain and which were master volcanoes in but comparatively recent time—Mount Taylor on the east and the San Francisco Mountains on the west. From the immensely thick and almost horizontal sediments that compose most of the mass of the plateau, layer after layer has been eroded away over wide areas, leaving remnants of harder strata which make picturesque hills and valleys and expose fossil forests which long ago were buried in the sediments of which these strata are made. Erosion has also carved many canyons, notably the majestic Grand Canyon of the Colorado.

Here and there in the rocky cliffs and canyons are the present and former communal homes of the aboriginal peoples, whose arts and religious ceremonies partly lift the veil of the past and reveal glimpses of the earlier stages of the human culture. These vast expanses were long ago the abode of aboriginal tribes; later they were explored and dominated by the mounted Spanish *conquistadores*; and finally they have been made accessible to all by the comfortable railway of today. The plateau country and its approaches, in all their aspects—geologic, ethnologic and historical—form a region which will hold the attention of all passers-by in whom there exists a spark of appreciation for striking natural phenomena and significant human events.

I quote further from the publications of the U. S. Geological Survey (Professional Paper 98-K, by F. L. Ransome) to get a broader description:

The plateau region, which has an area of about 45,000 square miles in Arizona, occupies the northeastern part of the state and drains generally northward through the Little Colorado and smaller streams into the Grand Canyon. The general altitude of this region, which is a part of the great Colorado Plateau, ranges from 7000 to over 8500 ft. As Dutton graphically states:

"Its strata are very nearly horizontal, and, with the exception of the Cataract Canyon and some of its tributaries, not deeply scored. Low mesas, gently rolling and usually clad with an ample growth of pine, pinon, and cedar; broad and shallow valleys, yellow with sand or gray with sage, repeat themselves over the entire area."

Here and there the Kaibab limestone (Pennsylvanian, late Carboniferous), the prevalent surface rock, is covered by flows of basalt or bears erosion remnants of younger strata; and above it, north of Flagstaff, rise the lofty extinct volcanoes of the San Francisco Mountains.

The southwestern limit of the plateau traverses in a general southeasterly direction from the Grand Wash Cliffs, near the eastern border of Nevada, to the New Mexico line, a few miles northeast of Clifton. This boundary along much of its course is a single bold escarpment 2000 ft. or more in height; but elsewhere it is less definite and less simple, owing to a distribution of the total difference in relief among a series of great topographic steps, or to local accumulations of volcanic rocks, especially basalt. In general, the outer or lower line of cliffs separates nearly horizontal and undisturbed strata on the northeast from faulted and tilted beds on the southeast; and locally, as along the Grand Wash Cliffs, this line is itself a fault scarp, more or less modified by erosion.

The Grand Wash cliffs rise precipitously 3000 ft. or more above the plains to the west. According to Lee, pre-Cambrian granite is exposed at their base and the Redwall limestone forms their crest and the floor of the adjacent plateau. About 45 miles east of the Music Mountains a second gigantic step, that of the Aubrey cliffs north of Seligman, carries the geologic section nearly to the top of the Kaibab limestone, which forms the surface of the Coconino Plateau, south of the Grand Canyon. South of the Music Mountains there is another ample terrace in the ascent from the valleys of the mountain region to the Colorado Plateau—that of the Truxton Plateau. This bench, which lies between the Cottonwood and Aquarius Cliffs to the west and Yampai Cliffs and Juniper Mountains to the northeast, is described by Lee as a granitic peneplain partly covered with volcanic rocks.

South of Ash Fork the continuity of the plateau escarpment it interrupted by flows of basalt that poured down from the plateau to the valley of the Verde, forming a slope that has been utilized by the Santa Fé, Prescott & Phœnix Ry. between Ash Fork and Jerome Junction. East of this railway and north of Jerome the edge of the plateau is in general a scarp (part of the Aubrey Cliffs of Gilbert) over 2000 ft. in total height, with deep reëntrants and bold pinnacled promontories.

Ransome in another place stops to say that the view from the mining town of Jerome—itself perched on a steep escarpment 2000 ft. above the valley—across the broad Verde Valley to these red cliffs, topped by a dark line of forest, all surmounted by the towering San Francisco peaks, is nearly, if not quite, as impressive as the Grand Canyon itself.

East of Camp Verde a thick series of basaltic flows, with associated tuffs, has covered the edges of the nearly horizontal sedimentary rocks; but these beds appear again at the head of Fossil Creek and continue eastward past Payson in the great southward-facing cliff that marks the descent of about 2000 ft. from the Mogollon Mesa to the Tonto Basin. From Fort Apache eastward to the New Mexico line, the plateau boundary becomes less distinct. Erosion has partly destroyed its continuity, and vast accumulations of volcanic rock have obscured the original plateau surface.

The second topographic division, the mountain region, which adjoins the plateau region on the southwest, is essentially a broad zone of short and nearly parallel mountain ranges, among which are the Dragoon, Chiricahua, Whetstone, Pinaleno, Galiuro, Santa Catalina, Pinal, Superstition and Mazatzal (and many others), extending diagonally across the state from the southeast corner to Colorado River. The width of the zone may be taken as from 70 to 150 miles, but its southwest boundary is not susceptible of precise demarcation. Few of the individual ranges exceed 50 miles in length or 8000 ft. in altitude. Their general trend is almost northwest, but near the Mexican border it becomes more nearly north, and the mountain zone as a whole coalesces with a belt of north and south ranges that extends through New Mexico, thus swinging around the plateau region and bordering it on the east also.

Most of these ranges consist mainly of quartzites and limestones of Paleozoic or earlier age, resting with conspicuous uncomformity upon granitic, gneissic and schistose rocks. All these rocks are cut by later intrusives, especially by diabasic and monzonitic rocks, and are partly covered by flows of lava. Structurally these ranges are characterized by the dominant part played by faulting as compared with folding. The great copper deposits of Arizona, so far as they are known, are all, except that of Ajo, within this mountainous zone.

I have quoted these descriptions more fully, especially in the case of the plateau region, than would at first seem relevant to a discussion of the mines, none of which are found in that area. But the contrast of the two areas is of great interest to the mining man because it shows so clearly that the mountain region, in which the mines occur, is a pronounced zone of weakness in the earth's crust. The plateau is like a great floe of arctic ice, through which cracks run at occasional intervals,

but on the whole it is solid and uniform. The mountain region resembles a fringe of hummocks bordering the floe, in which great blocks have been broken and tilted, some portions sloping far down below the general level and others jutting their angular edges above it. At three different epochs since the Paleozoic age has this rupturing taken place, and each time igneous molten rock has been squeezed up between and through cracks in the unstable blocks. These huge fragments are parts of the same massive plateau. The hummocks, of course, have been attacked by erosion, and the spaces between are filled with the débris which is still migrating slowly into the hollows.

The ore deposits, in all cases, are caused by gases or solutions escaping from the cooling igneous masses, carrying metals which they are able to dissolve while the heat and pressure are great enough, and depositing them when they lose some of their heat and pressure. This occurs when the gases escape into the inclosing rocks, or into such upper portions of the igneous masses themselves as may have already cooled. The relation between this action and the lines of structural weakness in the earth's crust is a simple and definite one, when broadly considered, and well worth noting. It is seldom that such a relationship is so clearly expressed in the surface topography as it is in the examples noted. Although this belt is described properly as the mountain region, its average elevation is considerably lower than that of the adjoining plateau, the loftiest peaks being little, if any, higher than the plateau summit. The average altitude is probably between 4000 and 5000 ft. The drainage is nearly all westward through the Gila and its tributaries, although a considerable area in southeastern Arizona and northern Sonora drains into the Yaqui River. All the drainage of the mining region goes finally to the Gulf of California.

Only on the higher summits will the Easterner see vegetation that looks familiar, with pines and junipers in abundance. The lower slopes and broad valleys take on varying aspects. Here, grassy plains and slopes littered with yellow gourds and interspersed with scattered live oaks; there, similar stretches clothed with a variety of thorny bushes, mesquites and greasewood; elsewhere, rocky knobs covered with ocatillas, palo verde and chollas—the most formidable and picturesque of the cactus family. Bare hills are made to look still more barren by weird forests of towering sahuaros—the giant cactus. Yuccas, in considerable variety, are found almost everywhere, with Joshua trees, Spanish bayonets, and soapweeds. Here and there one may see cottonwoods, black willows, hackberries, mountain ash, madrona, sycamore, black oak, manzanito, cherry, squawberry, ironwood, box elder, walnut, sage brush, and many others. The vegetation, of course, is not nearly so abundant, but seems quite as varied as in the well-watered countries of the east and north—so varied, so highly characteristic, and so well adapted to soil

and climate that it adds materially to the scenic wealth of the United States.

"Adjoining the mountain region on the southwest," to quote Ransome again, "is the third topographic division, the desert region, which also contains many short ranges of mountains of prevalent northwesterly trend. In this region, however, most of the ranges are separated by broad desert plains, underlain by fluviatile and lacustrine deposits of late geologic age, or by undulating granitic lowlands partly covered with gravels and flows of lava. The boundary between the mountain and desert regions is, as previously stated, indefinite, but may provisionally be taken as a curved line extending from Nogales, on the Mexican frontier, past Tucson and Phœnix to Needles, at the California line."

Ransome might have added that this territory is lower, has been generally stripped by erosion of the Paleozoic sediments that once covered it, and is characterized by a vegetation more emphatically desert-like than that of the mountain region. The giant cactus, the creosote bush, the cholla, the barrel cactus, the palo verde and similar weird and strange plants are found everywhere. Familiar vegetation has almost vanished, and the average white man feels himself to be in a strange land.

The striking feature of desert topography—and this is true of the mountain region to almost the same extent—is the interminable talus slopes, made up of rock fragments that have cracked off the fault blocks or volcanic piles which form the projecting heights and been carried into the lowlands by the gushes of water from occasional cloudbursts. Geologists have given considerable study to this phenomenon. It is a mistake to suppose that sedimentary beds are necessarily deposited in water. Desert regions generally are areas of deposition, and the streams are too feeble to carry onward all the debris that is offered them. Sometimes there are no permanent streams at all; many desert regions are enclosed basins with no outlet to the sea.

In both mountain and desert belts in Arizona, faults of recent geologic age have often formed lakes by interrupting the flow of streams. These lakes have been filled up in all cases, I believe, and the streams have surmounted or cut through the obstruction and resumed their erosion. The Roosevelt dam is merely the artificial replacement of a natural dam which had been thus cut through; and the new lake fills merely a part of an old one. In some of the depressions, the talus accumulations are surprisingly deep, attributable, no doubt, to recent faulting. The Miami Copper Co. drilled a hole 2000 ft. deep into the so-called Gila conglomerate, merely a talus accumulation of Quaternary age, without reaching the bottom. This depression is thus much deeper than any present channel of erosion, and indicates a great change of level in the geological yesterday.

Here again is a fact, seemingly irrelevant to our main subject, but

really important. These great accumulations of talus, or wash, occupy the larger part of the area both of the mountain and desert regions. The loosely compacted mass of angular and subangular fragments contains at every level abundant pore space, which enables it to fill an exceedingly valuable role in the conservation of the water supply. The occasional heavy rains pour floods from the mountains, which spread out over the talus slopes and playas. A large part sinks readily through the porous mass and reaches a level where its flow is impeded and often permanently stopped by barriers on the underlying rock surface. At the same time, this water is effectively protected from evaporation, and the lower portion of the accumulations is a succession of reservoirs of good water, which is utilized for mining, milling, and smelting plants as well as for towns, agriculture, and railroads. Thus the Gila conglomerate at Miami, already mentioned, furnishes water for the Miami and Inspiration mining companies. Part of the supply comes from the Old Dominion mine, the workings of which extend out under the conglomerate, and as a consequence are undesirably wet; but the heavy pumping consequently made necessary does not go entirely uncompensated, for the water is transferred to the Miami for use in that company's plants. The mines and town of Ajo are absolutely dependent on such a supply, as well as the large towns of Douglas and Tucson, with the various industries that support them. Many a valley is dotted with ranches which would not be there except for these talus reservoirs.

In still another respect this feature promotes human occupation. If erosion were in control of the surface of such a region, its fault-block mountains would be rough surfaces of hard rock, trenched with tortuous ravines and deep canyons, destitute of soil, and, in the long droughts, ten times more parched and unwatered than they actually are. As a matter of fact, the depressions are pretty well filled up in long gentle slopes, which support vast areas of good soil, besides rendering the country infinitely more accessible than it otherwise would be. The railroads are not forced to follow crooked canyons cut in hard rock, but are able to dodge around the ends of the detached mountain uplifts and traverse the country in fairly straight courses and easy grades over the desert-made talus.

In many places the upper, and, possibly, the lower portions of the wash are hardened by a lime cement, the exact origin of which is not exactly clear to me. Perhaps it is lime derived from the weathering of the feldspars in the granitic or volcanic detritus and spread over the surface by the flow of water after the heavy but intermittent rains, the lime taken into solution being precipitated by evaporation or by some other cause before it has traveled far, the flow of water not being abundant or persistent enough to carry it into a permanent stream and thus out of the country. However this may be, the process has evidently

a considerable effect on the topography of the wash in those extensive areas which are now being eroded instead of being built up. Tracts hardened by caliche are more resistant and tend to stand out in the form of low ridges, domes, or mesas. The caliche supports a rather scanty soil except in places favorable for the accumulation of dust. Wherever this caliche is exposed and strewn over the surface—for instance, in grading for streets and houses—it presents the forlorn and desolate appearance of old mortar.

Population and Ethnology.—I have already remarked that Arizona is geographically somewhat like Spain and Morocco, more particularly the latter. The configuration of the land is different in some respects, but the effect of the sun, the ocean, and the major air currents seems to be almost exactly the same. This similarity is expressed to the eye in a resemblance of landscape, vegetation and even in human life and arts. The northern strip of Africa is a frontier for dark-skinned races, which fill the tropical regions of the south. The white races of Europe have at intervals for thousands of years attempted to establish themselves on this border, but with no lasting success. The dark-skinned population has always swallowed up the white immigrants, or invaders. At times the races of Africa have been superior in arts and organization to the Europeans and have surged over and occupied the Mediterranean islands and the tips of the Spanish and Italian peninsulas, to be expelled again, leaving only minor after-effects on the population.

The copper fields of Arizona are in just such an ethnographic borderland. To the south is the dark-skinned Mexican race, upon which the Spaniards impressed their language and some of their arts, but not their color or their racial characteristics. To the north, in the colder plateaus, the white-American stock is rapidly swamping all racial competition and the Indian and Mexican population is already reduced to isolated fragments which have progressively less and less influence on their white neighbors. In the mountain and desert regions there is a racial deadlock. The organizing, industrial, and developing impulse comes from the white invaders, but there is no assurance that they will ever overwhelm the natives with their numbers.

The Mexicans resist absorption in a variety of ways. Though most of them speak or understand English, it is not their familiar tongue. Even in the schools, where all the teaching is in English, the Mexican children set themselves apart from the white children and immediately fall into Spanish. This language is invariably spoken in the household, even by those Mexicans who speak English so perfectly that one might imagine they knew no other tongue. This difference of language, added to difference of color, helps to perpetuate difference in habit and point of view; and all these things tend to restrain social intercourse between the two races. Industrially, the inhabitants of the region are not on the

same level. The Mexicans do not produce anything like the same number of business leaders, professional men, engineers, or trained mechanics. They are, therefore, less highly organized, and their group efficiency is far lower; for it is group efficiency that promotes productivity.

American and Mexican Methods.—The difference between the Mexicans and the whites in this respect is generally expressed in a difference of wages. When such a difference is imposed upon individuals who do the same work as white men there is an apparent injustice which leads to dissatisfaction. I would not like to try to arbitrate the difficulties which arise under such a state of affairs. A thousand Americans in a mine may produce twice as much from it as a thousand Mexicans, yet each American shoveler may not load any more cars than each Mexican shoveler. If the American shoveler is paid twice as much as the Mexican shoveler receives, the latter is not likely to see the justice of it. I can see no line of argument that seems likely to convince him; the question is too abstruse.

I am satisfied, however, that the laws of trade will inevitably impose a difference of wages. A mining organization of a thousand men, all Mexicans from the directors to the mule drivers, would almost certianly involve itself in mistakes of organization and engineering. I should expect that a white organization of the same number would avoid enough of those mistakes to enable it to produce twice as much ore with no greater effort. The result, in a competitive business, is bound to be the defeat and destruction of the Mexican organization. Only one thing can save it, and that is a willingness on the part of its members to accept low enough wages to allow the product to be sold at the price their competitor is willing to accept.

The actuality, so far as the mines are concerned, is a compromise. The Mexicans do not complete with the whites in finance, organization, management, or engineering; probably avoiding thereby the severe consequences of defeat. They do furnish a large part of the common labor; and the laborers, though not paid as much as white men, do undoubtedly reap some benefit from the organizing ability of the whites, because they get much higher wages than when they work under Mexican employers. In some places they are paid the same as white men.

It is easy to see, on the other hand, how the Anglo-Saxon imagination has been impressed by the sight of a Mediterranean civilization in an environment that is natural to it. Both the Spaniards and the Moors inherited much from the Romans, Phœnicians, and the predecessors of those peoples. Their architecture and their agriculture were developed to combat a blazing sun and long droughts. The word "rival" is a reminiscence of ancients quarrels over water rights. The fig, the olive, the orange, the date, and the grape are natural neighbors of the live oak, the yucca, the cactus, and the creosote bush. The massive walls of

stone or mud, covered with stucco; the flat roofs, inner courts and gardens protected from wind and dust; the heavy porticos, or *portales*, refuges from the fierce sun—all are so natural under such an environment that they seem inevitable. Several different races have invented them independently. The architecture of the Pueblos and Aztecs bears a strong resemblance both in form and material to that of Morocco, Sicily, Syria, and Persia.

The Americans have brought with them an architecture inherited from the rainy climate of northern Europe and the eastern United States; steep roofs to shed the rain, many windows to make the most of the scanty light, spreading lawns and stately trees outside the house to serve as grateful reminders of aboriginal meadows and forests. They have brought, also, many appliances for heating, lighting, cooking and communication—products of their mechanical skill which are useful everywhere. But in many respects the north European forms do not fit in with the southwestern environment, and they are being rapidly modified under the guidance of experience, and with the growth of wealth, education, and good taste, to conform with standards which long human use has shown to be appropriate. In other words, the Yankees are earning much from the Mexicans.

CHAPTER XIII

JEROME AND THE PRE-CAMBRIAN

DESCRIPTION OF JEROME, ARIZONA—SUGGESTION OF GEOLOGIC HISTORY—UNCONFORMITIES—THE ALGONKIAN OR BELT SERIES IN THE WEST—PARALLELS OF THE PRESENT DAY—PROBABLE ORIGIN OF JEROME DEPOSITS DURING OROGRAPHIC REVOLUTION AT THE END OF ALGONKIAN TIME—PARALLEL IN LAKE SUPERIOR—STRUCTURE OF JEROME DEPOSITS—THE UNITED VERDE—THE UNITED VERDE EXTENSION—ECONOMIC VALUE OF PRE-CAMBRIAN LAND SURFACE—OUTPUT AND PROFITS OF MINES—THEIR FUTURE—DISCUSSION OF DEVONIAN GEOGRAPHY—ITS BEARING ON THE MINES OF THE MAYER DISTRICT. EROSION OF A DOME DURING POST PERMIAN TIMES—THE MAYER MINES—REMARKS ON THE ENGINEERING OF PROSPECTS.

Jerome is one of the most spectacular places in the United States. When an automobile road has been built direct from Prescott, it will be only 31 miles from that town. On that highway the tourist will come upon the Verde Valley first over the flank of Mount Mingus, and will find himself looking down over an escarpment 4500 ft. high. The picture will give him a thrill. Even after months of looking at it, much is found that has previously escaped notice. It is more than a scene of relief and color; it is a vast exposure of present-day geological processes, volcanoes, and erosion, and of important geological facts reaching back to the earliest recorded ages. By collating all these features, one finds that the panorama builds up an interest even exceeding that of the Grand Canyon. Fifteen or twenty miles away, straight in front across the valley, is the same great mass of colored strata that appears in the Canyon, but here forming only the front of the great plateau. On the summit 60 miles away, are the San Francisco peaks, looking like Mount Shasta. In the bottom of the valley are glimpses of the river, amidst clouds of smoke from two great smeltery stacks, which, at this distance, look like pipestems.

In the discussion of this district, I am venturing to explore some of the dim realms of geological speculation which mining engineers usually avoid. I would have no desire to do this if there were not reason, more or less vague and hardly capable of clear expression, for thinking that these speculations follow a line which may lead to practical results.

No longer can there be any doubt that the study of ore deposits, from the point of view of pure science, has become part of the essential equipment of a mining man. Secondary enrichment, the magmatic origin of ore deposits, the effects of contact and regional metamorphism, the indi-

cations of such action in rock alteration, and many similar things are absorbed by hosts of men who have never consciously studied geology. It is far from impossible that a study of the history of earlier continental geography may lead to further knowledge of the areas of mineralization.

Familiarity Often Breeds Misunderstanding.—Nothing is more common than for people to assume that they understand things because they see them often. A view of the moon through a good telescope is, to the average man, an astounding revelation—all the more so, the greater the man's intelligence—although nearly everybody sees the moon every month, and the average man has read of it and has a fair idea of what it is. There is nothing difficult about it. He may see the moon as plainly as he can see the house across the street: mountains and plains, bright sunlight and impenetrable shadow; lofty mountain pinnacles whose summits are aglow with the rising sun; a clear view of a sphere, not a flat disk—a huge object with an area greater than the United States and all its outliers. But did he realize it? He will probably have to confess that he did not. But, once he does, he will have no doubt that it is worth while, although the knowledge will never bring him a cent. Similarly, how many stop to realize that the unconformable parting of two rock formations is a record of great events and changes? That dividing plane is, at once, the surface of an ancient continent and the floor of an ancient sea. The fact is perfectly intelligible; it requires no extraordinary effort of the imagination. The only obstacle to overcome is the habit of not observing and thinking about such things.

Geologic Unconformities at Jerome.—One of these unconformities is so conspicuous at Jerome that it serves as a starting point for the mining operations. The miners in half the district are exploring, not the present land surface, but the surface of a continent that was buried many millions of years ago. In a way, it is part of another world; not wholly inaccessible, like the moon, but probably less understood. Fragments of the pre-Cambrian surface are exposed at different places, but rarely more than its edges are brought to light. It is just as important to realize that this old surface may be destroyed by deep erosion, so that its most valuable and interesting features are lost, as it is to realize that the larger part of it is inaccessible because it is buried; more so, in fact, because there is a chance that part of the buried portion may be exhumed. In these tattered edges of the old continent are many valuable ore deposits—the iron mines of Michigan and Minnesota, the zinc mines of New Jersey, the old iron mines of Southeast Missouri, the gold mines of the Black Hills, and, no doubt, many others. Exploration, groping along this old surface, prompted by geological speculation, led to the discovery of the wonderful copper bonanza of the United Verde Extension. This single incident justifies a lot of speculation.

Of course, there is no profit in letting one's imagination run riot,

creating pictures which are nothing but dreams. It is, however, possible to use the imagination as a searchlight to explore the dark world of possibility. In that way it may lead to many a solid fact.

Study of the mines of Jerome reveals a setting of impressive facts which point the way to some equally impressive conjectures.

1. The ore deposits were developed (geologically) into their present condition during the erosion of a continental area. This period of erosion continued for an exceptionally long period, speaking even of geologic time, for it resulted in wearing the continent down to a nearly level plain (peneplain), which was finally submerged slowly and quietly by an invasion of the sea. This submergence persisted during long ages of Palæozoic time with no greater disturbance than occasional gentle oscillations. of level. The period of erosion had followed a period of mountain building which was, in all probability, exceptionally severe and widespread and was accompanied by volcanic or batholithic action on a grand scale. It appears, then, that the period of erosion, as well as the succeeding era of deposition during Palæozoic time, represents a long epoch of quiescence and extremely slow differential subsidence, following a period of disturbance during which the mountain-building forces in this part of the world had exhausted themselves.

2. The ore deposits are a part, or result, of almost the latest pre-Cambrian igneous action to be seen. The rock masses most intimately associated with them are not highly metamorphosed or disturbed; they are markedly less so than any of the older-pre-Cambrian rocks which occur in the neighborhood.

3. Neither the ore deposits nor the rocks in which they occur differ in any essential respect (unless age is an essential) from deposits in nearby districts which were formed during the later mountain-building periods that brought to an end the long-continued submergence, sea invasion and marine deposition of Palæozoic, and again of Mesozoic, time.

4. The period of deposition which immediately preceded the pre-Cambrian continental uplift was an active and extensive one. It is represented by the Belt series of rocks, which are thick masses of sandstones or quartzites or conglomerates, shales and limestones—all prevailing ripple-marked or sun-cracked, and containing some sparse remains of animal life thought to be chiefly fresh-water forms. At any rate, the evidence is positive that most of the Belt rocks were formed either on land surfaces or in shallow water, and were probably piled up in river deltas, playas, lakes, estuaries, and perhaps shallow arms of the sea or tide flats.

Characteristics of Belt Rocks.—These Belt rocks were tilted, faulted, folded and metamorphosed during the latest great pre-Cambrian continental uplift, but they were not generally distorted or metamorphosed to anything like the extent to which still earlier rocks had been. In fact,

they are found to lie upon them in positions of nonconformity as abrupt as that which separates them from the succeeding Palæozoic rocks. Some of these still older rocks are also, without doubt, sedimentary; that is to say, they were once sands or muds. The separation between the Belt rocks and the still earlier ones therefore took place during a prior period of continental uplift, mountain building, and erosion which had followed upon an even more primitive age of quiescence, subsidence and deposition.

The Belt rocks are thus so characteristic that they may be recognized with fair certainty wherever they are well exposed. They are found in large patches, some of them areas of thousands of square miles, extending from not far north of Roosevelt Dam, in Arizona, to central British Columbia, northwest of Banff—a distance of 1300 miles north and south, and within a strip about 500 miles wide east and west. Jerome lies about 100 miles northwest of large exposures described by Ransome in the Tonto Basin and about 75 miles slightly east of south of other large ones in the bottom of the Grand Canyon. About 200 miles northeast of the latter are large exposures in the Needle Mountains, in southwestern Colorado; 200 miles northwest of the Needle Mountains, across vast masses of later sediments, are found similar great exposures in the Wasatch Mountains of Utah; 75 miles further northwest, they occur along the Bear River, in Utah; and 225 miles further north begin the great areas of Belt rocks in western Montana, which extend thence far northwesterly through the Cœur d'Alene region of Idaho into British Columbia. Due west of Jerome in the Inyo Mountains of California are further exposures.

Deductions from Acknowledged Facts.—I have recited these facts in order to show the broad basis for the following conjectures, which appear to me to be reasonable:

1. The Belt formation is the filling of a great epicontinental depression or trough which was either filled as fast as it sank or sank because it was filled, so that during the whole process its surface was fairly level and low. One cannot be sure, of course, that there were not two or several basins with interruptions between; but even if so, the conditions in all were substantially the same. This parallelism of conditions over so wide an area could have been induced only by a dominant influence sufficiently potent to dwarf local influences. It is noticeable that the Belt rocks contain stupendous quantities of fine sands, grading in fineness down to true silts, and alternating. Coarse pebbly sands, to say nothing of heavy conglomerates, are rare. It is, therefore, plain that these materials must have been transported far enough to break up effectually all the coarser products of erosion; but at the same time the detritus was delivered into the settling area constantly and in great volume.

It seems to me that such conditions of combined uniformity and

volume over such extended areas must indicate the neighborhood of a great mountain chain, or at least an extensive belt of highlands on one side or both sides of the trough. It is not necessary to call upon a direct effort of imagination to find an explanation; the geography of the present day offers a number of examples from which to choose.

The great uplift of the Himalayas is bordered on both sides by similar areas of deposition. On the south side is the Ganges flood plain, covering 300,000 square miles, in which recent sediments borne by the Ganges and Brahmaputra are known to be over 2000 ft. deep and may continue to accumulate in the future almost without limit and without pronounced change in their character. The vast plains bordering the Sea of Aral are a similar field, being filled with detritus brought down by the Oxus and the Jaxartes, and with dust and sand swept in by desert winds.

Parallel Instances in North America.—Or one may turn to North America to find several other examples; namely, the Gulf of California, the upper end of which has already been filled across by the detritus of the Colorado River, so that its northern extension has been cut off and the water there has evaporated, leaving a large area below sea level. This trough is 800 miles long, 100 to 150 miles wide and is receiving sands and silts of both rivers and winds from a vast area of erosion. The valley of California, 400 miles long and 75 miles wide, between the Sierra Nevada and the Coast Range is being filled with detritus of the same nature, already known to be over 2000 ft. deep, and is sinking as it fills.

Still another example, on a scale and of a nature sufficient to make a parallel with the Belt rocks, is the great coastal plain of north America beginning at Long Island and extending along the coast through Georgia Florida, Louisiana, and Texas into eastern Mexico—a distance along a gently curved line of fully 2000 miles, with a width up to 500 miles, and receiving the detritus of all the rivers on both sides of the Appalachian Mountains, and from the Rocky Mountain uplift for 2000 miles, from Tampico to Alberta. It receives the sands migrating down the Missouri and the Arkansas, the Rio Grande, the Nueces, the Guadalupe, the Brazos, the Red River, the Mississippi, the Ohio, the Alabama, the Flint the Savannah, the Potomac, the Susquehanna, and the Hudson—513,000,000 tons a year of sand and mud, besides 270,000,000 tons of salts in solution. This whole coast is an interminable stretch of fine sands, assorted by waves and shore currents, piled up on the shore in dunes This mass has been accumulating and slowly shifting without striking interruption since the beginning of Upper Cretaceous times, and no one knows how deep it is.

At any rate, the Belt rocks represent some such scale of grand continental features, great mountains and great rivers, debouching upon a huge subsiding basin or slope for ages under conditions generally as and stable as those on our Gulf Coast today. In this great basin there

was little volcanic activity. It is probable that there was some, but it certainly was hardly more prominent than it has been along the coastal plan—no greater than that in the valley of California in recent times.

Volcanic Activity Follows Period of Slight Action.—When this cycle of deposition came to an end, however, there was an outburst of mountain-building energy on a great scale, accompanied by volcanic activity and batholithic action. Before this ended, the Belt rocks were hardened, tilted and folded, and finally subjected to erosion so widespread and long continued that the enormous accumulations of rock were wholly swept away over large areas, until they remained only in depressed tracts or synclines; such, for instance, as one found in the bottom of the Grand Canyon, where sediments not less than 12,000 ft. thick are found as a mere remnant protected from the general destruction through having been squeezed into a trough that extended below the level of effective attack. At the tops of these troughs the tilted beds of quartzite often project some distance into the overlying rocks, showing that before the erosion had been completed they had become harder and more resistant than the neighboring granites and schists, and had formed low hills and ridges in the rolling plain which was the expression at once of a worn-down continent and of a cycle of recurrent geological agencies.

Theories of Formation of Jerome Deposits,—From this assemblage of fact and inference, I believe it is possible to make an intelligent conjecture that the ore deposits of Jerome were formed from igneous action which accompanied the uplift and mountain building that occurred at the end of the Belt period of deposition. The diorites of Jerome in which, or along which, the orebodies occur are comparatively fresh and massive. This fact is marked enough to make it seem certain that they had not participated in the metamorphism, deformation and erosion of the continent that preceded the Belt rocks. The fact that the Belt formations contain practically no interbedded volcanic material, both in general and in the areas nearest Jerome in particular, is good and almost positive evidence that this extensive igneous activity did not take place during the period of Belt deposition. It is possible, therefore, to come naturally to the conclusion that the Jerome rocks appeared during the uplift which brought the Belt period to an end. Under this assumption, I can see no difficulty whatever in picturing the succession of events. As was the condition with the Belt rocks, the Jerome intrusives suffered the long-continued erosion and oxidation which continued in the mountains of the post-Beltian and pre-Cambrian continent. Like the Belt quartzites. they finally projected as low hills, covered with reddish soil—hills so low that they would have attracted little attention in the slightly rolling landscape.

There are no Belt rocks at Jerome and none are known nearer to it than the Grand Canyon. These supposed relations between the Jerome

ore deposits and the disturbances which ensued upon the termination of the Belt period of deposition are not based, therefore, upon direct evidence but rest upon conjecture, or, to call it by a more dignified name, upon a process of reasoning. But it diminishes the scope for guesswork, and adds something to the probability of my conjecture, to find that in the bottom of the Grand Canyon there are copper deposits which have precisely the broad geological relations which I have pictured for those of Jerome. L. F. Noble describes these deposits as fissure veins which cut across both the Unkar Group (Algonkian or Belt) and the underlying Vishnu schists (Archæan). To be specific, the facts are as follows;

1. The Unkar group contains great intrusions of diabase, similar, no doubt, to some of the rocks at Jerome. The copper-bearing veins are fault fissures cutting the Unkar rocks but terminating at the overlying basal sandstone of the Cambrian. Speaking of these deposits, and of the conditions of formation, Noble says;

> All the other deposits in the Archæan and Algonkian rock occur either in similar fissure veins, which represent the mineralized fault planes of normal Algonkian faults or in the zone of shattering along the line of the Algonkian displacement of the West Kaibab fault. All the faults belong to the same period of displacement, the one in which the great mountain-making movement came at the end of Algonkian time.

Formation of Jerome Deposits Contemporary to Those of Lake Superior and Canada.—2. If it be logical to regard these conjectures as measurably correct, there is reason to argue that the ore deposits of Jerome may belong to the same cycle of continental history as the copper mines of Lake Superior, the copper-nickel deposits of Sudbury, the silver deposits of Cobalt, and perhaps the gold mines of Porcupine, Ontario and the zinc deposits of New Jersey. These deposits are all connected with batholithic, or at least volcanic, masses along a tolerably well-defined axis. They may all belong, as has been suggested to me by Prof. C. K. Leith, to the same period of mountain building. The broad fact, on which conjecture may be based, are as follows:

The Upper Huronian, or Animikie, series of Lake Superior, as well as certain earlier rocks separated from the Animikie by an erosion interval or moderate unconformity, is an example of normal sedimentation on an extensive scale. Following a long period of continental quiescence, during which erosion forms had reached mature stages, there ensued a slow subsidence and sea invasion. The first deposits were sandstones or conglomerates, merely the washed débris of land weathering; following these were chemical deposits or precipitations such as usually take place in deepening waters, limestone and the peculiar iron formations; finally, deposits made after the subsidence had come to an end, and erosion products from the land rapidly filled the shallowing basin—shales and sandstones.

Then followed an outburst of mountain building or continental readjustment, during which certain areas of the rocks described were dislocated and contorted, just as rocks have been dislocated and contorted along many mountain-building axes in other places in later times. This disturbance was accompanied by igneous activity on a tremendous scale, producing innumerable batholiths or intrusions, as well as great piles of surface volcanics or extrusions. The Keweenawan series, the copper-bearing rocks of Lake Superior, was such a pile. It consists of a succession of thick lava flows separated by beds of coarse erosion products or talus, such as invariably accumulate on mountain slopes. As the process went on, the volcanic activity lost its vigor, the intervals between eruptions became longer, the accumulations of débris greater, until finally the eruptions ceased altogether and the lowlands around or the depressions between the volcanic piles were swamped in a huge mass of talus which differs in no essential respect from the wash that fills the depressions between the fault blocks of Arizona.

It seems to me that this Keweenawan series, then, is distinctly a record of continental disturbance, the reverse of the period of quiescence and marginal deposition of which the Huronian is the record. With the closing of the Keweenawan disturbance, the Lake Superior region settled into a state of crustal quiescence which has lasted to the present day. During Palæozoic and again in Cretaceous times it was quietly depressed, so that it received a partial invasion by the sea, the record of which is sediment still undisturbed and almost unconsolidated. In all its major aspects, this succession of events is on all fours with that recorded for the Belt series, the mountain-building interval, and the Palæozoic of central Arizona; and it is a fair inference that the copper deposits of Jerome belong to the same line in the geological column and to the same set of general causes as those of Michigan.

Structural Features of Jerome Ore Deposits.—A great deal remains to be learned about the structural features that govern the occurrence of the deposits in the Jerome district, but one salient fact appears to be established—the ores are distributed along the contacts of intrusive masses of an augite diorite. All the masses of this diorite now known may easily have been originally one, which has been divided by faulting, but this is not yet a definitely proved fact. This diorite is next to the youngest of the pre-Cambrian rocks of the district, but it is cut by a set of dikes which are also a kind of diorite, but are narrow. The orebodies are younger than the great diorite intrusions but older than the narrow dikes. The massive diorite, which may be designated the United Verde diorite; the orebodies and the narrow dikes, which are known by the rather extraordinary name of "water courses" are all undisturbed except by recent faulting, and plainly did not participate in the mountain-building stresses which affected the other pre-Cambrian rocks. They are, however,

definitely pre-Cambrian in age. The whole process of formation was completed, the ores were exposed by erosion, oxidized to a depth of 500 ft., the copper had migrated to the zone of secondary enrichment, and the orebodies brought completely into their present condition before the invasion of the Palæozoic sea.

The rocks cut by the United Verde diorite are all ancient volcanics, either intrusive or extrusive. Some of them may be of pre-Algonkian age, on the theory that the United Verde diorite is post-Algonkian, because they have been subjected to stresses vigorous enough to give them a widespread schistosity; and I suppose this must indicate that these rocks participated in mountain-building movements that occurred before the Belt rocks were deposited.

Relation of Greenstones and Quartz Porphyries,—The oldest rocks seem to be prevailingly greenstones, many of which are undoubtedly extrusives, often in the form of bedded tuffs, although a good many of these are of medium acidity and have a gray or dark color. These greenstones are often considerably folded, in axes running, generally, north and south. Into these greenstones a mass of quartz porphyry has been intruded, and forms the high ridge called Cleopatra Hill, just south of the United Verde mine. It is with this north border of the quartz porphyry mass that the present article is chiefly concerned, for the zone of mineralization follows it fairly closely.

As a whole, the quartz porphyry is a large irregular mass the outlines of which are vaguely known as its west end, but not at all toward the east, where, beyond a great fault, it is generally covered with Palæozoic limestones and recent lavas. It is certainly intrusive into the greenstones and irregular in outline, probably sending off several spurs from the main mass, and extends along an approximately east-and-west course from south-west of the United Verde to and beyond the Texas shaft, a distance of two and one-half miles. The north boundary of this mass cuts across the bedding or schistosity of the greenstones nearly at right angles and forms a rude plane, which dips generally northward at an angle of perhaps 60°. It is a notable fact that this prophyry, which in its center approaches a granite in texture, has been strongly sheared, and a pronounced schistosity has been developed in a large part of it. Some portions, however, especially the southwestern part, have been much less affected by the shearing and are still massive. The pronounced schistosity begins at the United Verde mine and continues eastward as far as the rock is exposed on the surface. This schistosity has a strike of about N 20° W and occurs in bands of greater and lesser intensity.

So far as known at present, the intrusions of United Verde diorite do not penetrate into the mass of the quartz porphyry, but seem to follow along its contact. Sometimes the diorite cuts across branching arms of the quartz porphyry and in places comes in contact with the main mass,

but large wedges of the schist are included between the irregular boundaries of the two intrustions. It would appear that the greenstones near the contact formed a weak zone, which was followed, at least in a general way, by the dorite intrusions. As intimated previously, the diorite is strikingly fresher than the older rocks, and the contrast between its massive structure and the extremely schistose part of the quartz porphyry attracts immediate attention. As the diorite is patently a younger rock, one is inclined to wonder why it did not force itself in along the planes of schistosity, instead of going across them; but that it did not do so warrants the conclusion that the greenstones border must have been, on the whole, less resistant than even the most schistose bands of the porphyry. All the known valuable orebodies of the Jerome district occur in these greenstone schists, which form the border of the quartz porphyry, or are within the latter rock near its periphery.

At the United Verde mine, the orebodies are in a large slab of greenstone schists, in horizontal cross-sections resembling a rude crescent, which pitches downward between its enclosing intrusives, in a northwesterly direction, at an angle of perhaps 50 to 60°. The diorite covers this slab of schist with a concave surface like an inverted Spanish tile, and the quartz porphyry forms a rough pitching floor. If the included schists were removed, there would be an enormous cavern going down steeply to the north.

The schists which fill the space that I have thus attempted to descibe have been the channel of an intense mineralization, so that a considerable part of them has been converted into ore. This ore consists essentially of quartz, pyrite and chalcopyrite. The thing that attracts the eye is an enormous mass of iron pyrite, occupying a cross-section of nearly if not fully 10 acres, rudely circular or elliptical in outline, but irregular. The quartz and chalcopyrite are mingled with this mass in varying amounts. Near the center of the pyrite mass there is not, as I understand it, much quartz, although the amount increases toward the periphery; but this arrangement is far from regular. The chalcopyrite is the ore. The mass of the pyrite contains only one-quarter of 1 per cent. copper—being practically barren—but certain portions of it contain chalcopyrite in varying amounts, so that large lens-like masses attain a copper content ranging from 2 per cent. up to 15 or 20 per cent. These are the orebodies. Chalcopyrite also occurs in the schists around the periphery of the pyrite masses and also makes orebodies. The ores contained in the pyrite mass are called iron ores; those consisting of chalcopyrite disseminated in the schist are called siliceous ores.

Narrow Dioritic Dikes Cut Orebodies.—These broad features are unmistakable, and may be regarded as thoroughly established; but, as a matter of detail, the occurrence of the commercial ore, as distinguished from the mineralization as a whole, presents many eccentricities that are

not wholly understood. The orebodies are cut by several narrow dioritic dikes, known as water courses. These are usually considerably bleached, even in the lowest levels, far below the influence of any alteration proceeding from the surface. This would seem to indicate that the dikes have been altered by the mineralizing agencies. On the other hand, there is no evidence that they have been replaced by the ore minerals. It seems reasonable to conclude, therefore, that they came in during the latest stages of the mineralizing process. These dikes have a strike which may be generalized as about N 70°W; and many observers have concluded that the dikes may have followed a zone of fissuring which might have existed earlier and have been followed by the mineralization. If this was the case, there is little evidence of it in the orebodies themselves, for the minerals now form a solid mass in which preëxisting structures have been obliterated as completely as in a stock of granite.

But away from the centers of intense mineralization, in the Jerome Verde and United Verde Extension mines, some fissures have been noted that bear in the same general direction as the water-course dikes and are distinctly, though not heavily, mineralized. This lends color to the idea that a zone of fissuring may have had much to do with establishing the mineralizing channels.

New Mineralized Area Developed.—The United Verde Extension mine has in recent years opened up a mineralized area about two-thirds of a mile east of the United Verde. Ignoring for the present other interesting facts about these occurrences, there is reason to believe that they are part of the same zone as the United Verde. But the structural arrangement is still indistinct, because the development is only partial and because all of it thus far is in the zone of oxidation or in that of secondary enrichment, in both of which the rocks are greatly altered by kaolinization. In the immediate neighborhood of the orebodies, therefore, it is hard to distinguish some of them. It seems, however, that some of the smaller orebodies follow the contact of a great wedge-shaped mass of diorite between the quartz porphyry and the green schists. These ores are between the diorite and the schists. But the great orebody of the Extension mine is not so easily described. It is at the point or edge of the wedge of diorite and is surrounded apparently on all sides by quartz porphyry, but is near the contact of that rock with the green schists. Moreover, it lies apparently at the intersection of two interesting mineralized faults, one of which strikes about N 65° E and the other about N 70°W.

It is evident that in the region of the big orebody the United Verde diorite is invading the contact between the quartz porphyry and the green schists, but whether the diorite follows a pre-existing fault, or whether the faults are later than the diorite, is very obscure. The mineralization is intense over an area of several acres, in the central

part of which an area of an acre and a half is a solid body of chalcocite and pyrite averaging 17 per cent. copper.

It is rather early to generalize about orebodies that are so meagerly developed, but it looks as though the vast masses of pyrite, which are a sort of matrix for the orebodies of the United Verde, are comparatively small in the Extension mine. Low-grade pyritic masses have been encountered, it is true, but thus far they are relatively insignificant, and it is not improbable that they will continue so even in the zone of primary ores. If this proves to be the case, it will only mean, in my judgment, that the Extension orebodies are more distinctively copper mineralizations than those of the United Verde. In the latter mine, the copper ores seem to have been introduced after the formation of the main pyrite masses. The later copper-bearing mineralization is probably identical in both mines. There is no reason to believe that the United Verde Extension bonanza was any richer as originally deposited than some of the individual orebodies at the United Verde; but it does seem probable that, in the Extension, the proportion of copper to the total volume of iron is very much higher. So far as can be judged at present, the two deposits are about equal as copper producers. Even making all allowances for the effect of secondary enrichment, it is doubtful if the United Verde orebodies contain more copper, if as much, per vertical foot, as those of the Extension.

Another point of great economic importance is the fact that the two parts, or halves, of the district are separated by a great fault. On the hills above the United Verde, the flat-lying sandstones and limestones of Devonian age begin to appear at an elevation of 6050 ft. The fault has an average strike of N 37° W. East of this is a bench, on top of which the same sandstones and limestones lie almost perfectly flat, but their bottom is at an elevation of 4350 ft. The vertical displacement is, therefore 1700 ft., and in this bench lie the Extension orebodies. Other faults occur further east, dropping the Palæozoic formation to a still lower level, so that by the Verde River, at Clarkdale, only three miles away, the pre-Cambrian floor is only 2000 ft. above sea level. None of these faults except the big one at Jerome has raised the pre-cambrian rocks to the surface. East of that fault they have remained buried since the invasion of the Palæozoic sea. It is all but certain that in the succeeding ages, including the present era, they have never emerged above the ground-water level. They are, therefore, preserved intact, having suffered neither oxidation nor erosion since the day they were buried. On the United Verde side, however, the great recent fault exposed the pre-Cambrian rocks in an escarpment 1000 ft. high above the bordering bench. This escarpment has been beveled off by recent erosion. Above the United Verde mine, 600 ft. of the orebodies has been removed by this erosion, including nearly all of the original oxidized zone. The primary sulphides in places come up to the present surface.

Now, the oxidation plainly acted more vigorously in the larger orebodies than in the smaller ones, and the copper migrated further. If there had been smaller orebodies in the vicinity of the United Verde, the enriched portions, as well as the oxidized zone, would have been swept away, leaving only the ores of the primary zone at the present eroded surface. A small vein carrying 3 or 4 per cent. copper would not be valuable. On the other side of the fault, such small veins are still intact, oxidized zone, enriched zone, and all. In the enriched zone they carry fair bodies of chalcocite, running 15 to 45 per cent. copper. Such small veins are, therefore, valuable and make a pleasing adjunct to the big ones.

Great Amount of Low-Grade Ore in United Verde.—As in other districts where rich ores occur in abundance, the operators have naturally preferred to mine those rich ores in preference to poorer ones. It is, therefore, difficult to form an idea of the average grade of all the merchantable ores. It is certain that large amounts of low-grade ore, say from ½ to 2½ per cent. copper, occur in the United Verde mine. Some of this material goes into the shipping product, inevitably, because the miners cannot always keep it out, but no effort has been made to utilize it. How much there is of it, how cheaply it can be mined, the extent to which it could be concentrated by flotation, are all unsolved problems, and any assertion about them would be pure guesswork. However, I regard it as probable that in the course of time it will be found desirable and practicable to concentrate some of the low-grade ores; and the life of the mines will be greatly prolonged by so doing.

Output from United Verde Mine.—At present the United Verde mine is able to ship to its smeltery an assemblage of ores, practically all primary, averaging about 5 per cent. copper and yielding about 90 lb. copper, 1½ oz. silver, and 35c. gold per ton. It may be assumed that this grade was much higher in the earlier years of the mine and that it has slowly declined. It is probable, however, that by careful mining the grade may be maintained at its present level for a number of years, although it is planned to increase the output to 1,000,000 tons a year, increasing the present tonnage by about 15 per cent. This will mean that the output of copper will rise to 90,000,000 or perhaps 100,000,000 lb. a year in the near future. The assurance that this can be done is furnished by the discovery or a large body of high-grade chalcopyrite ore in the lower levels of the mine, from 2100 to 2500 ft. below the original pre-Cambrian surface. This orebody, I understand, runs about 10 per cent. copper, and a large section of it, opened for stoping, has averaged nearly 13 per cent. A cross-section of the orebody near its middle would apparently cover at least an acre.

On the United Verde Extension side 202,477 dry tons of ore has been shipped up to the end of 1917, entirely from the richest part of the zone

of secondary enrichment, from which the actual yield has been about 104,000,000 lb. copper, 375,000 oz. silver, and 7000 oz. gold. The grade of ore, as shipped, has averaged about 27 per cent. copper, 1¾ oz. silver, and 70c. gold per ton. It is not believed that such ores can be shipped much longer, but there is no reason to suppose that the grade will go below 10 per cent. copper for a number of years. In fact, one may be fairly certain that the first 2,000,000 tons mined will average 15 per cent. copper. If this rate is maintained, will, say, 10,000,000 tons of United Verde ore over a 10-year period beginning in 1915, the date of the opening of the Extension mine, the average grade for the district for that length of time will be not less than 6⅔ per cent. copper. This is high-grade ore, considering that it is obtained without sorting of any kind; but it is no richer than the average of the Bisbee district to date. When one considers the fact that this ore is being mined at depths varying from 400 to 2500 ft. below the pre-Cambrian surface; that none of the mines is exhausted at any level; that the Extension mine has no development at all more than 800 ft. below the pre-Cambrian surface, and almost none below 600 ft.—that, in fact, the exploration of the zone east of the fault is hardly more than well started—it may reasonably be expected that these mines will make a big output and have a long life. In 1917 they produced 135,000,000 lb. of copper, and are being equipped to produce 150,000,000 to 200,000,000 lb. a year. There is no reason to suppose that such an output will put an undue strain upon the ore reserves. Thus Jerome, which for 25 years was an isolated and obscure camp, is now becoming an important producer. I shall try to give some idea of the community as an industrial and mining center.

Up to the present, from an output of something less than a billion pounds of copper, the two mines of Jerome have paid $50,114,000 in dividends. They have also built, out of earnings, two large smelteries, a considerable length of railroad, extensive tunnels and mining equipment, two or three rather important industrial towns, completed or under way, and have, no doubt, large amounts of cash in the treasury. A rough computation of the operating earnings up to the end of 1917 is not less than $80,000,000. Of this, perhaps half has been earned during the exceptional years 1916 and 1917 from and output of 225,000,000 lb. There is good reason to suppose, however, that the earnings on 700,000,000 lb. during normal peaceful times were about $42,000,000, or 6c. per lb. There is also reason to believe that if the output of the last two years had been made in normal times, with a price of 15 c. per lb. for copper, the operating profits would have been $20,000,000. Thus, I believe the past history of the camp indicates an average operating profit of about 6½c. per lb. and a cost of about 8 to 9 cents.

It appears that up to the end of 1915, the United Verde mine had been able to pay $36,397,000 in dividends in a period of 21 years, during which

the price of copper had averaged 14.3c., the production being fairly uniform at about 35,000,000 lb. a year. Five cents has been available for dividends, leaving a net cost of 9.3c. per lb. to cover all expenditures for mining, smelting, development, construction of railroad and smeltery, general expenses, and increase of working capital. The net yield per ton has probably averaged about 100 lb. copper, 1½ oz. silver and 40c. gold. The average value of the precious metals figures down to about 1¼c. per lb. of copper, so that if the average price of that metal is 14.3c., the total value of the bullion will be 15.55c. On this basis, a liberal allowance for all expenses, both for operating and capital, on a total output of 700,000,000 lb., has been 10.05c. per lb. The cost of converting, refining and marketing the bullion may be estimated at 1.85c. per lb., leaving 8.2c. per lb. for all other expenses.

United Verde Extension Possibilities.—Apply these figures to the extraordinary bonanzas opened by the United Verde Extension, in which 2,000,000 tons of ore can be counted on to run 15% copper and to yield 290 lb. copper, 1½ oz. silver and 60c. gold per ton, with operating methods equally efficient as those of the United Verde. The value of this bullion is 14.8c. per lb. Deducting 1.85c. per lb. for converting, refining, and marketing, there remains 12.95c. per lb. The mining, smelting, construction, and general expenses will be, as before, $8.20 a ton, to be divided by 290 lb. copper. This is equal to 2.83c. per lb. Deducting this, there remains 10.12c. per lb., which should be applicable to dividends. I can see no flaw in this reasoning, although the result appears extraordinary.

It is fair to believe that the total output of copper, 580,000,000 lb., according to this computation, would be extracted in 10 years, and that dividends of $60,000,000 would be paid in that time, leaving the mine intact for further development and a complete equipment. Under these circumstances, it seems to me that the investor is warranted in figuring that the $60,000,000 profits expected in 10 years is a conservative and guarded basis for valuing the property; that he might assume a 5% net return, plus return of capital, to be sufficient for a property so guarded, and that he would have important speculative probabilities in addition. Under these circumstances, it is computed that the property possesses a valuation of $45,000,000.

The "speculative probabilities" refer to the discovery of additional ores. There is likelihood of such discoveries, both laterally and in depth. Exploration in depth has gone down only one-third as far below the original surface as in the United Verde, in which mine bonanza or occurs in the very bottom.

Before ending the discussion of the pre-Cambrian deposits which have proved so valuable at Jerome, it will be interesting to note the extension of the same formations to the southwest. At Jerome itself there is

merely a narrow point of a wedge of pre-Cambrian, raised up through a cover of Palæozoic sediments by faulting, aggregating in vertical movement 400 ft., which has taken place along a zone a mile and a half wide. It is thus upon the escarpment of an important recent mountain uplift. The Palæozoic formations at Jerome present two peculiarities that are worth noting:

1. The series begins with the Devonian, at least that is my supposition. The lowest limestone is known to be Devonian, and between it and the pre-Cambrian complex there is only about 50 ft. of sandstone. Ransome assumes that this sandstone corresponds to the Tonto sandstone (Cambrian) of the Grand Canyon, but I take this to be merely a slip of the pen. It is hardly possible for a few feet of sandstone to carry with it any presumption of equivalence in age with some other sandstone that looks like it. Each invasion of the sea produces a basal sandstone by reassorting the weathered débris on the land surface. Such a basal sandstone merely marks the sea transgression, and the same one might, and no doubt does, mark the progress of the sea upon higher and higher levels of a continental area through a series of geologic ages. In the absence of determining fossils, the age of such a sandstone should be assumed to be that of the contiguous rock overlying, if that is determinable.

Now, throughout Arizona there are usually some Cambrian strata in the Palæozoic column, but the Ordovician and the Silurian are generally wanting. Ordinarily, there is no angular unconformity between the Cambrian and the Devonian, in spite of the huge time gap represented by the absence of the Ordovician and Silurian. To explain this, one has only to remember that in Russia, along the Gulf of Finland, Cambrian and Ordovician strata are still unconsolidated sand and clay. They have lain there through interminable ages without change, distortion, metamorphism, or even hardening, because the earth's crust in that region has remained still. It is entirely conceivable that, around Petrograd, Quarternary strata may be in contact with and in apparent conformity with the Ordovician.

Interesting Geologic Facts and Deductions.—In Arizona the absence of unconformity between the Cambrian and the Devonian must mean simply a long period of quiet, with gentle oscillations of level, and no deposition; certainly no mountain building, and no deep erosion. In Devonian times there followed a general immersion in the sea of this whole region. By this time the neighboring lands, wherever they were, must have been worn down so flat that they could furnish little or no clastic sediment, for the Devonian rocks are almost pure limestones. From Cananea to Grand Canyon and from Tucson to Clifton, and no one knows how much further in all directions, there was a sea of clear water of moderate depth, and full of corals and coral reefs.

An interesting question which may be solved some time is whether the highlands southwest of Jerome may not have been an island in this Devonian sea. The absence of strata older than the Devonian and the strong inference that there had intervened no considerable disturbance or erosion, which was likely to have swept away such strata in pre-Devonian times, point decidedly to the conclusion that there was comparatively high land at the site of Jerome which the Cambrian sea did not reach. This naturally brings up the question whether the slope may not have continued in some direction toward a *massif* high enough to remain an island even during a large part, or all, of the succeeding submergence.

Assuming that the Devonian strata were originally level, it is possible to calculate that the pre-Cambrian surface at Jerome was originally 1000 ft. higher than the same surface at Grand Canyon, there being that amount of Cambrian strata under the Devonian at Grand Canyon and none at Jerome. The same facts appear in comparing the sections of Bisbee, Ray, Globe, and Roosevelt Dam (Ransome). As all these places lie toward the southeast, east and north, it is easy to explain the facts by a depression along axis lying northeast of Jerome, and therefore approximately under the edge of the plateau region. If this is true, it is logical to assume that the land surface sloped upward toward the southwest. How far this slope continued, or to what height, one has no means of knowing, except that there is good reason to believe that in Devonian times the slopes were gentle, erosion was slow, and no large rivers were debouching near enough to muddy the waters.

2. The Palæzoic strata are found at the very top of the Black Hills (the mountain block on the edge of which Jerome stands), but they merely lie on the outer rim of the uplift, and do not continue toward the southwest for more than a mile or two. They appear to feather out. There is no indication of their having been broken off by further faulting.

I do not refer to this fact as evidence of the thinning out of the Palæozoic deposition in that direction. That conclusion must be based on broader facts than those I am pointing to. It appears that the edge of the Palæozoics occurs as fragments of an arc of a curve the radius of which is about 25 miles, and its center some distance southeast of the town of Prescott. The fragments of this arc are found on the crest of the Black Hills west of Camp Verde and east of Prescott, thence northwest along the crest of the Black Hills to near Jerome Junction. At Jerome Junction there is a gap, but just north of that place the edge of the Palæozoics may be covered up with recent lavas. Six miles west of Jerome Junction the Palæozoics appear again in a strong ridge running west. All along the rim of this arc the strata dip gently away from the center.

Practical Importance of Geologic Considerations

I think there is warrant for believing this structure is the remnant of a dome or arch that was formed in Tertiary times, if not earlier, and

extensively eroded long before the occurrence of the big faulting at Jerome or the late Tertiary volcanic activity of the region. If the Palæozoics be projected along their dip into the Prescott region, they would be found thousands of feet above the present surface. In the area now under consideration, this means that the original pre-Cambrian land surface does not exist in the sense that it exists at Jerome—i.e., intact but buried—but that there does exist, instead a new erosion surface scored down more or less during long geologic ages.

I believe these observations to have practical importance, for without them it would be difficult to understand the deposits of the Prescott region, or to have any logical conception of the relationship between them and those of Jerome. The present surface of the scored dome just described is strewn with much recent lava, probably of the age of the San Francisco peaks. There are also many remnants of older volcanics, or intrusives, many of which are too fresh and undisturbed to have participated in the intense mountain-building activities of pre-Cambrian and pre-Algonkian time. There may be many igneous rocks of ages anywhere from Permian to Tertiary. Some of the ore deposits which have been worked in this area, off and on, for the last 50 years, may be derived from these comparatively recent intrusions. I suspect this to be the case with the copper mines at Copper Basin, about eight miles southwest of Prescott.

The Mayer Copper Mines.—The far more important and promising copper mines near Mayer, 20 miles southeast of Prescott, are patently pre-Cambrian and are not to be explained as emanating from later igneous activity. The largest mine in this district, the Blue Bell, is 30 miles south and 10 miles west of the United Verde, and about 20 miles west of the nearest Palæozoic rim. The original pre-Cambrian surface in this locality has undoubtedly been scored down at least 2000 or 3000 ft., but the exact amount I have no present means of estimating. If, therefore, these deposits may be assumed to have had about the same relation to the pre-Cambrian surface as those of Jerome (a mere assumption certainly, but let it go at that), one must conclude that the Mayer mines represent a deeper-seated stage of mineralization.

In the Mayer district the rocks are known as Yavapai schists. They appear to be ancient surface volcanics for the most part, mainly greenstones of about the composition of diorite or diabase. There are no doubt plenty of intrusives mixed in. The copper deposits all occur in some quartz porphyry dikes which cut the greenstones and strike about N 10° to 15° E. Many of these rocks have been subjected to an extraordinarily energetic squeezing which has produced in all of them a schistosity that strikes N 28° E. It is so strong in places that the quartz porphyry looks like a light colored and very fissile slate.

There is one important difference between these deposits and those of

Jerome—there is no United Verde diorite or anything like it. The orebodies are all within or on the contacts of the squeezed dikes of quartz porphyry. In all other respects they are similar, but smaller and not so rich. The Blue Bell mine has produced to date about 600,000 tons of ore, and has 500,000 tons more in sight above the 1200-ft. level. In 1917 this mine shipped about 120,000 tons of ore, averaging a shade over 3 per cent. copper and $1.50 per ton in gold and silver. About half this ore is concentrated; the other half is massive pyrite, much like that of the United Verde. The Blue Bell orebodies are easily mined, the cost of mining under present conditions being a little over $3 a ton, including development. On a return to pre-war conditions this cost would be reduced to about $2.25 per ton, delivered to the railroad. There is no apparent reason why such ores should not be valuable under normal prices.

In all this discussion of the Jerome and contiguous district, I have gone only slightly into the details of cost. The fact is, the district displays little of special interest in this respect, and the reports of the mining companies give meager details. The striking features are precisely those already dwelt on; the geology, the big faults, the rich concentrations of ore, which allow low unit costs for copper without much regard for costs per ton mined: and the corollary that successful mining is largely successful exploration. In the whole area considered there are seven or eight mines that have dealt with deposits such as those described. Of these, two are wonderful bonanzas. The others are either mediocre producers, like the Mayer Mines just mentioned, or immature prospects, Canyon and a few others. One, the Copper Chief, southeast of Jerome, is working, for gold, the oxidized gossan of a large pyrite deposit which has proved unprofitably low in copper. In addition to these there are many prospects, some of which are mere wildcats and others genuine enterprises testing various theories as to the location of possible extensions of mineralized areas.

In all this fervor of exploration, a detached and unprejudiced observer may find one lesson worth noting, namely that exploration of new ground for possible ore deposits demands the same attention to adequate equipment and adequate finance as the mining of ores actually found. Vast sums of money have been squandered through loss of time and failure to accomplish the work planned—by trying to make two horsepower equal four horsepower. Shafts too small and too insecure, hoists that will not raise the load from the required depth, pumps that will not handle the water, result finally in no room for ventilation, injury to health of the men, and meager results: and often the whole job, instead of being a question of drilling holes and breaking rock, becomes a blind and useless struggle with bad air, broken pipes, rotten timber, heat, water and mud.

The spectacular development and success of the United Verde Ex-

tension are due almost wholly to good prospecting engineering. The project had been going on in some such fashion as that described in the preceding paragraph for I don't know how many years. It had been started with enthusiasm, but with little calculation, by a man named Fisher, on a small fraction called the Little Daisy, right on the great Jerome fault. A shaft had been sunk 800 ft. through this fault into hard quartz porphyry. All lateral workings had to go out through the fault again. A winze had been sunk, again along the fault, to the 1200-ft. level. All this work had dug up some indications of ore, but the practical result was failure and discouragement, and the enterprise was considered to be a mere wildcat.

When James S. Douglas and George E. Tener decided to undertake the prospect, they applied common sense to the situation and came to a sound conclusion. It would cost $250,000 to explore the ground, anyway, and this amount of money, spent in a safe shaft with good equipment, would accomplish the work more cheaper and quickly than is would if spent in the old shaft. They accordingly sank a new shaft 1400 ft. in a central location in solid rock. When they struck ore, they were able to ship it immediately in good volume. Their new shaft was sufficient, as things turned out, to make an output of 63,000,000 lb. of copper a year, and to make profits at times exceedig $1,000,000 a month. That part was luck, of course, under any interpretation of that rather uncertain word, but good management consists of so acting that when luck comes your way you can make the most of it. I suppose that if no ore had been found, the level-headed gentlemen who created the mine would have been pointed to as victims of overconfidence—a renewed warning against (some phase of) the danger of building a mill before you find a mine. The indictment would have been false. They took a true measure of the job as a piece of pure prospecting.

CHAPTER XIV

LAKE SUPERIOR COPPER MINES

Remarks on geology—Résumé of costs in 1911—General working conditions—Plants required—Cost of smelting—Three types of deposits—Ordinary amygdaloids—Wolverine, Ahmeek, Allouez, Isle Royale, Osceola—Baltic lode—Champion, Trimountain, Baltic—Conglomerate lode—Tamarack, Calumet and Hecla.

The Lake Superior district, for a long time almost the sole producer of copper in North America and still a prominent one, has lost some of its comparative importance in the past ten years through the continued growth of production along the Pacific seaboard in North, and also in South America. In 1909 it produced some 21 per cent. of the copper of the United States and 13 per cent. of that of the world, but in 1916 its proportions had been reduced to about 13 and 8 per cent. respectively.

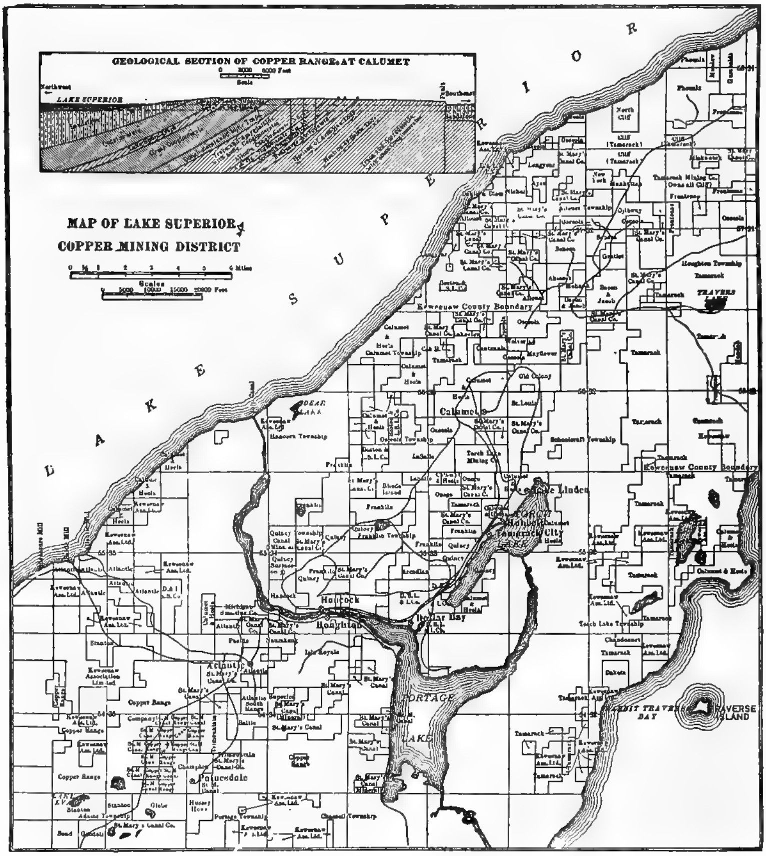
In the preceding chapter some hint was given of the broad facts of pre-Cambrian geology, linking the Lake deposits to the same chain of events that produced those of Jerome. Presumably the same kind of relationship covers also the copper-nickel ores of Sudbury, Ontario, the unique silver deposits of Cobalt, the gold mines of Porcupine and the unique zinc deposits of Franklin Furnace, New Jersey. In fact nearly all these pre-Cambrian districts present unique and striking features; but they differ from each other as much as they differ from deposits of later age.

The copper bearing rocks of Lake Superior cover a wide area but the productive portion is a tract about 50 miles long upon the Keweenaw peninsula and the adjoining mainland, on the central portion of the south shore of the lake. The bulk of the formation perhaps lies under the waters of the lake, being exposed on the principal islands. It was a huge, but local, pile of volcanic rocks which was built up apparently along the flank of the post-Algonkian mountain range which was formed to the southward and after the Huronian rocks had suffered considerable compression and erosion. The Keweenawan rocks do not offer the appearance of having been greatly folded, but rather the tilting, quite steep in places, that might be accomplished along the edges of a great subsiding mass. They are not otherwise disturbed or altered, except by a few moderate faults.

In the five years 1906 to 1910 inclusive the twelve principal mines, three of which were unprofitable, had the following record which I be-

lieve exhibits more correctly than any other table the general aspects of the business under pre-war conditions.

Tons rock stamped	40,000,000
Total yield, pounds	1,000,000,000
Yield per ton, pounds	25
Receipts from sale of copper	$149,806,420
Average price per pound	14.98 cents.



Redrawn from Map by R. M. Edwards, Houghton, Michigan.

FIG. 4.

COST OF PRODUCTION

		Per ton
Mining, transportation and smelting	$ 79,626,898	$1.98
Smelting (partly included in mining)	8,404,386	.21
Construction	8,885,002	0.22
General expenses	3,687,476	0.09
Miscellaneous	1,110,844	0.03
Total expense	$101,714,067	$2.54

Cost per pound copper 10.1 cents.

This calculation agrees in all essential respects with the record for twenty years 1890 to 1909 inclusive, during which the average price was 13.7 cents, the profits slightly under 4 cents per pound and the cost something over 9.7 cents per pound, except that in this period there had undoubtedly been a decline in the yield per ton. Under pre-war conditions therefore we might conclude that the average profit was not far from 4 cents a pound, this being somewhat under 30 per cent. of the selling price of the metal. This was a margin of profit that few other districts have been able to equal.

It will be seen from more specific data which is inserted with reference to particular mines, that the yield per ton, especially under the stimulus of war conditions has continued to decline. Engineering projects have been undertaken by the chief mines to match this decline of yield by a reduction of costs. How far this effort has succeeded is at present obscured by the disturbance of the economic factors which has not subsided far enough to make comparisons reliable. It was the goal of the Calumet and Hecla management, for instance, to secure "dollar rock;" that is to mine and mill the ordinary amygdaloid for $1.00 per ton. They never reached this goal, although it will be seen from the appended statements that some of the mines, the Osceola for instance, came near it in 1912 and again in 1915.

In 1911 I estimated that about 3,000,000,000 pounds of copper to be obtained from some 150,000,000 tons of rock could safely be counted on. This was doubtless an underestimate of the ultimate output, but it is certainly true that the exhaustion of the richest mine, the Calumet and Hecla conglomerate, will remove a producer that is not likely to be replaced. The Champion mine has made some valuable developments and the Quincy has not suffered from the caving which at one time promised to put an end to, or seriously interrupt, the operations, but in general it must be conceded that the district is already on the wane. Up to date it has produced over 7,000,000,000 pounds of copper. According to my estimate of 1911 something like 1,600,000,000 pounds remain to be added to this. Whether the district can produce much more than this amount that will be profitable in like proportion and under the same conditions as that already produced still remains to be seen. It is to be remembered that declining districts often make a large yield on which the margin of profit is scanty or wanting.

Here follow some remarks retained from the first edition.

The Lake Superior copper mines work deposits of native metal occurring either in beds of conglomerate or in amygdaloids, which mark the upward surface of ancient lava flows. The deposits in these beds form immense ore shoots of dimensions in one case as great as three miles in length and over a mile in width in the plane of the vein, covering many hundred acres. Such a lateral extent, combined with a thickness

of from 6 to 30 ft., gives a volume of many million tons of workable material.

The persistence and extent of the deposits have long established that the controlling factor in the successful exploitation of these mines is the provision of machinery for handling large quantities of material for long periods of time. The practice prior to 1908 fixed a cost of about $1,500,000 as necessary for the preliminary development and equipment of a property on a scale commensurate with economy. The actual working of the deposits is simple. The mines are dry and safe; the ores of each deposit are uniform in character and can be concentrated easily and cheaply; the smelting operations are reduced to a minimum, the concentrates to be smelted ranging from 1 to 4½ per cent. of the ore milled. Wages are very moderate, being about 25 cents an hour; supplies of all kinds are cheap; the country in the neighborhood of the mines is well watered and well timbered; transportation to and from markets is done mainly by water, and is very cheap. The population is vigorous and intelligent, although at least 95 per cent. of the men employed in the mines are of foreign birth, the greater number being Finns, Englishmen, Austrians, and Italians.

It may be said, therefore, that not a single factor in the working of the mines is unfavorable. The inclination of the deposits is from 35° to 70°, so that in following the ore shoots the shafts become enormously deep, several of them being in the neighborhood of a mile vertically below the surface. This means, of course, an unusual expense for hoisting and increasing difficulty in working as compared with mining at ordinary depths, but it indicates the remarkable persistence of the orebodies. Under present conditions the total cost of mining these ores and marketing the copper is from $2 to $3 per ton.

Plants Required and their Cost.—To elaborate a little on the business aspects of the process of obtaining the copper we may group the plants required as follows:

1. *The mining plants for hoisting, pumping, compressing air, crushing etc.*—These plants are always owned by the mining companies themselves. Unfortunately I am not able to get the cost of these plants, segregated from other plant charges, in a single instance.

2. *The transportation of ore to the mills.*—This is invariably done by railroad. The Copper Range Company had to provide this equipment for three mines which in 1906 had reached an output of 1,828,000 tons and are likely to average 2,000,000 tons a year. The cost of the Copper Range Railroad was, including working capital and equipment, $6,500,000. This road serves a number of other mines and a considerable territory outside the Copper Range group. Nevertheless it seems fair to charge half of it to those mines, so that we may figure $1.60 per annual ton for their transportation capital.

3. *The concentrating mills.*—The cost of these is invariably bound up with that of the mine equipment and development. We may as well stop to consider 1 and 3 together:

The Copper Range Mines had to raise the following sums for development and mine and mill equipment before they became self-sustaining.

Baltic	$ 800,000
Trimountain	1,200,000
Champion	1,475,000
Total	$3,475,000

for an annual output of say 2,000,000 tons, equal to a plant charge of $1.75 per ton of ore stamped annually.

The Wolverine Mine paid for its mining and milling plants and development, if I understand the report correctly, $780,000; providing capacity for mining and milling 350,000 tons a year, equal to $2.20 per annual ton.

The Mohawk Mining Company spent $1,350,000 to provide itself with mining and milling facilities for an output of 675,000 tons, equal to $2.00 per annual ton. Its Traverse Bay Railroad went in with the mine itself, apparently, at a valuation of $450,000, or about 70 cents per annual ton.

Returning to the Copper Range and adding together the initial cost of railroad and mining plants we get a total of $6,800,000 or $3.40 per annual ton.

4. *The smelting plants for converting the concentrates or mineral into ingot copper.*—These plants are usually owned by groups of mines in common. The Michigan Smelting Company, with works capable of turning out 90,000,000 lb. refined copper a year, which represents the yield of about 4,500,000 tons of ore from the mines, is capitalized at $500,000, probably its cost. This is equal to only 11 cents per ton of rock mined.

Companies that have complete mining, milling, transportation, and smelting facilities of their own are the Quincy and Calumet & Hecla. The former states that its total cost for plant, including railroads, warehouse, real estate, smelting, mining, and milling plants is $6,300,000. The annual tonnage stamped is not given, but is approximately 1,100,000, giving a total plant cost of nearly $6 per annual ton. The Calumet & Hecla gives the complete cost of all its plants at between fifteen and sixteen million dollars, with an annual output of 2,500,000 tons, equal to $6 + per annual ton.

In round numbers, I think we may say that the minimum plant cost per annual ton is $3 for the most favorably situated amygdaloid mine and $6 for a conglomerate mine. In each case the working is conducted on a grand scale.

While the Michigan mines are all remarkably long lived it does not seem proper to reckon on anything less than a 7 per cent. annual instal-

ment to cover the amortization of capital so invested. The corollary is that the use of capital is worth from 21 to 42 cents per ton of output, or at the very least 1 cent per pound of copper.

Cost of Smelting.—Professor L. S. Austin reports (*Mining and Scientific Press*, April 24, 1909) the costs of the Lake Superior Smelting Company for 1906 as follows:

41,177 tons "mineral" (concentrates) producing 55,526,088 pounds fine copper.

		Per ton concentrates
Reverberatory operating	$195,144	$4.741
Miscellaneous	43,409	1.055
Construction	15,665	0.380
Blast-furnace operating	32,623	0.790
Miscellaneous	13,461	0.327
Total	$300,302	$7.293

Dividing the total cost by the pounds of copper we get 0.541 cents as the cost of smelting per pound.

It appears that to this must be added about ½ cent per pound for freight for market and marketing expense, so that the total cost for smelting, refining, and marketing is a little over 1 cent per pound refined copper.

Nature of the Deposits.—While in a broad sense the conditions are rather uniform throughout the district, there are three fairly well marked types of deposits whose characteristics impose certain differences of method and cost. One is the conglomerate, of which the only commercially valuable deposit is the great ore shoot worked by the Calumet & Hecla and the Tamarack mines. This has already produced in the neighborhood of 1,100,000 tons of fine copper from more than 40,000,000 tons of ore, and there remains in sight probably 20,000,000 tons more. This magnificent orebody is about 14 feet thick; it dips at an angle of 37°, and is a hard compact bed of conglomerate overlaid by a trap hanging wall of such a character that it requires timbering.

The amygdaloid deposits are rather numerous and have much in common. There is, however, an important distinction between that of the Copper Range Consolidated Company and the other amygdaloid mines. The ordinary amygdaloids (represented by the Wolverine on the Kearsarge lode and by the Quincy mine) either are, or are assumed to be, homogenous, in that all of the vein stuff is sent to the mill with a very moderate amount of sorting at the surface. These deposits have yielded from a minimum of 12 lb. to a maximum of 50 lb. of copper to the ton. The rock is softer than the conglomerate, and is more easily milled. The hanging wall is generally firm, so that in most cases mining can be done without any timbering.

The amygdaloid of the Copper Range Consolidated Company on the Baltic lode is somewhat different. The rock is harder than the ordinary

and the copper is very apt to be attached to numerous small fissures that traverse the bed. The result of this distribution of value has been the development of an entirely distinct type of underground mining, based on a system of sorting waste out of the vein itself and leaving this waste in the stopes for filling.

The Wolverine Mine.—Of these various types the simplest is the kind of amygdaloid mine represented by the Wolverine. This property in common with all others of the Stanton group is very well managed and issues clear and excellent reports. The entire process of mining and realizing copper at this mine is simple. The vein averages about 15 ft. thick. It dips at an angle of about 37°; no timbering whatever is required but a few small pillars are left. The shafts are sunk mainly in the vein itself, but partly in the foot-wall a few feet back from the vein. Levels are run at distances of 100ft. and are opened by what are called "stope drifts," these being a complete section of the vein 25 ft. wide along the plane of the footwall. The cost of running these drifts is $5.68 per foot in excess of the cost of stoping an equivalent amount of ground.

In the stopes themselves, nothing is done except to break the ore with machines. Once broken the ore is caught on a low platform built at the bottom of the stope from which the ore is partly rolled and partly shoveled into the cars. This completes the mining process. The cost of the underground work is less than $1 a ton; 7 cents a ton is added for crushing and sorting in the rock house at the surface. Transportation to the mill costs about 16 cents a ton and concentration about 22 cents. General expenses such as superintendence, taxes, and insurance, etc., amount to about 22 cents more; and smelting, refining, and marketing about 29 cents, making a total of operating expenses of $1.84. Construction work for the last four years has averaged 8 cents, and the total expenses with construction for the same period have averaged $1.92.

It is to be noticed that in this mine the exploration work is reduced nearly to zero. The whole operation is a straight, uncomplicated matter of handling so much material; and to the handling of it nature has interposed as few obstacles as can be found in any underground mine. There is very little water to pump; there are no complex vein systems to work out, no faults to interrupt the vein, and no geological relations to be understood. There is always abundant room to work, good ventilation, comparatively soft ground, and no timbering. While it cannot be denied that the Wolverine is a well-managed property which has kept notably clear from extravagant, impractical projects of all kinds, it seems fair to say that the low costs obtained by it are not in any way extraordinary, but merely the inevitable result of common-sense methods applied to a favorable set of conditions.

The accompanying table gives such details as are published of the cost of mining in the Wolverine. It is to be noticed that the Wolverine is at present the richest of all amygdaloid mines and that for this reason

the cost for smelting is higher than that of any of the other mines of its class.

Working Expenses at the Wolverine Mine, Year Ending June 30, 1907.

			Per ton
Underground Expenses (Rock Stamped 344,062 Tons)—			
Sinking 450 ft. at $17.88		$8,046.00	
Drifting 4,993 ft. at $5.68		28,385.80	
Stoping 23,175 fathoms at $7.69		178,269.70	
Labor		1,546.55	
		$216,248.05	
Timbering		5,286.60	
Tramming		71,603.15	
Mining captains and labor		29,151.80	
Mechanics		7,833.15	
Hoisting and pumping		22,092.51	
Compressor		29,774.52	
Teaming, etc.		1,095.95	
Supplies and fuel		19,107.47	
Electric light		291.88	
		$402,584.98	
Less profit on supplies furnished contractors		65,416.00	
		$337,168.98	$0.98
Rock House—			
Labor	$13,371.85		
Machinists	1,166.28		
Fuel	2,160.00		
Supplies	3,621.29		
Teaming, etc.	808.30		
Electric light	1,167.12		
		22,294.84	0.065
Stamp Mill—			
Transportation	$55,053.35		
Supplies and electric light	9,918.72		
Machinists	4,318.90		
Fuel and teaming	26,816.00		
Labor	27,632.80		
Pumping	7,599.78		
		131,339.55	0.38
Surface and Incidental Expenses—			
Superintendence and labor	$20,309.57		
Supplies	9,523.51		
Telephone, telegrams, and sundries	495.28		
Taxes and insurance	48,938.14		
Freight on mineral, etc.	5,948.28		
	$85,215.18		

Less amounts received for rents.........	6,547.90		
		78,667.28	0.223
		$569,470.65	$1.648
Construction average of four years........			0.08
Amortization of $780,000 at 5 per cent. interest and 3 per cent. annual amortization			0.20
Smelting, refining, and marketing.........			0.284
Total...............................			$2.212

Average cost of copper in New York, 7.93 cents per pound.

The amortization in this case includes the purchase price of the property. This tem is not distinguished from the capital invested in equipment.

The fore-going shows the aspect of this industry in 1909. For the later history it seems better to refer to the groups of mines under the management of the Calumet & Hecla for which excellent reports are now to be had. A summary of the results of all the profitable mines in the district for the years 1906—1910 inclusive is given.

Ahmeek.—The Wolverine mine is now on the decline. The property in which the general conditions most closely resemble it is the Ahmeek. It will be noted that the costs in 1913 were very much higher than the average.

Comparative Results for the Four Years

	1910	1911	1912	1913
Tons of rock treated...........	530,365	598,549	652,260	383,749
Cost of mining, transportation, stamping and taxes per ton of rock........................	$1.42	$1.42	$1.39	$1.77
Pounds of mineral obtained.....	16,758,521	21,917,925	23,945,315	13,742,140
Pounds of refined copper produced......................	11,844,954	15,196,127	16,455,769	9,220,874
Per cent. of refined copper in mineral......................	70.68	69.33	68.72	67.10
Pounds refined copper per ton of rock treated..............	22.3	25.4	25.2	24.0
Cost per pound:				
Mining expense.............	7.93c.	5.61c.	5.51c.	7.38c.
Construction................	1.85c.	0.32c.	1.20c.	4.53c.
Smelting, freight, commissions, eastern office, etc............	1.16c.	1.19c.	1.14c.	1.39c.
Interest....................	0.11c.	0.05c.	0.00c.	0.00c.
Total cost per pound refined copper......................	11.05c.	7.71c.	7.85c.	13.30c.

COMPARATIVE RESULTS FOR THE PAST FOUR YEARS

	1915	1916	1917	1918
Tons of rock treated	948,874	1,164,010	1,271,275	1,196,541
Cost of mining, transportation, stamping and taxes per ton of rock	$1.26	$1.46	$1.74	$2.18
Pounds of refined copper produced	21,800,492	24,142,158	28,919,812	24,851,235
Pounds refined copper per ton of rock treated	23.0	20.7	22.0	20.8

This was due to a labor strike. In this mine it may be computed that the development work required is only 1 ft. to 87 tons. The dividends paid in the period covered by the statements amount to $11,250,000 from about 165,000,000 pounds, nearly 7 cents a pound.

UNDERGROUND WORK FOR THE PAST FOUR YEARS

	1915	1916	1917	1918
Sinking No. 1 shaft, ft.	27	186	80	0
Sinking No. 2 shaft, ft.	82	196	289	119
Sinking No. 3 shaft, ft.	66	263	263	202
Sinking No. 4 shaft, ft.	0	161	332	122
Total	175	806	964	443

	1915	1916	1917	1918
Openings No. 1 shaft,				
Drifting, ft.	478	2,000	1,895	1,869
Openings No. 2 shaft,				
Drfting, ft.	1,605	2,238	4,058	3,881
Crosscutting, ft.	913	2,262	663	468
Fork, ft.	0	0	0	101
Openings No. 3shaft				
Drifting, ft.	2,943	3,154	3,364	1,788
Fork, ft.	14	0	38	0
Crosscutting, ft.	0	231	0	0
Openings No. 4 shaft,				
Drifting, ft.	2,641	2,935	6,067	4,932
Fork, ft.	0	.28	0	22
Crosscutting, ft.	0	0	0	24
Total	8,594	12,848	16,085	13,085

Allouez Mining Company.—Although this is an old mine it never paid any dividends until 1915. Since then it has paid $2,850,000 from an output of 36,000,000 pounds, 8 cents a pound, indicating complete costs of about 15 cents a pound. The production cost per pound in 1918 were mining 15.45 cents., smelting refining and marketing 1.47 cents: total 16.92 cents.

COMPARATIVE RESULTS FOR THE PAST FOUR YEARS

	1915	1916	1917	1918
Tons of rock treated	534,705	566,960	566,674	514,888
Cost of mining, transportation, stamping and taxes per ton of rock	$1.365	$1.589	$1.869	$2.119
Pounds of refined copper produced	10,043,459	10,219,290	8,892,915	7,071,218
Pounds refined copper per ton treated	18.78	180.2	15.69	13.73

UNDERGROUND WORK FOR THE PAST FOUR YEARS

	1915	1916	1917	1918
Sinking No. 1 shaft, ft	45	144	99	191
Sinking No. 2 shaft, ft	0	0	0	0
Total	45	144	99	191
Openings No. 1 shaft, ft	1,485.5	1,339.0	1,594.5	855.5
Openings No. 2 shaft, ft	3,373.0	2,164.5	1,243.5	1,903.0
Total	4,858.5	3,503.5	2,838.0	2,758.5

Total Depth of Shafts

No. 1 shaft 72 feet below 22d level, 3,980 feet from surface.

No. 2 shaft 198 feet below 21st level, 3,407.5 feet from surface.

SUMMARY OF RESULTS

	1915	1916	1917	1918
Rock hoisted, tons	535,718	567,858	567,459	515,150
Rock house discard, tons	1,013	878	785	262
Percentage of discard	0.189	0.158	0.137	0.046

The Centennial similarly has been making a little money. It produced copper in 1918 for 15.7 cents a pound.

Isle Royale Copper Company.—This is an interesting case of a mine being operated 60 years before it was made to pay. Perhaps I ought to take this fact as a personal rebuke, for I have frequently argued that the

value of hopes so long deferred might be put down at zero. I suppose the fact that the mine pays, and shows no apparent signs of failing to do so, is due to the good management of the group of men now in charge.

In eight years 132,000 feet of shafts and drifts were opened for about 6,400,000 tons of rock hoist, 1 ft. to 49 tons. Half of this work was done for the first third of the output. I imagine that doing this was what made the mine pay.

In 1918 the cost of producing copper was only 13.49 cents for mining and 1.58 cents for smelting, 15.07 cents altogether. That was pretty

Comparative Results for the Four Years

	1910	1911	1912	1913
Tons of rock treated	520,860	457,440	531,105	314,679
Cost of mining, transportation, stamping and taxes per ton of rock	$1.42	$1.47	$1.54	$2.12
Pounds of mineral obtained	10,433,060	10,339,171	11,461,410	5,887,000
Pounds of refined copper produced	7,567,399	7,490,120	8,186,957	4,158,548
Per cent. of refined copper in mineral	72.53	72.44	71.43	70.64
Pounds refined copper per ton of rock treated	14.5	16.4	15.4	13.2
Cost per pound:				
Mining expense	9.75c.	8.97c.	10.01c.	16.07c.
Construction	0.16c.	0.25c.	0.20c.	0.73
No. 7 shaft	0.00c.	0.00c.	0.15c.	0.27c.
Shaft "A" and explorations	0.33c.	0.07c.	0.05c.	0.01c.
Unwatering Huron mine	0.00c.	0.06c.	0.08c.	0.10c.
Smelting, freight, commissions, eastern office, etc.	1.26c.	1.21c.	1.31c.	1.53c.
Interest	0.34c.	0.29c.	0.09c.	0.10c.
Total cost per pound refined copper	11.84c.	10.85c.	11.89c.	18.81c.

Comparative Results for the Past Four Years

	1915	1916	1917	1918
Tons of rock treated	680,280	925,419	922,160	974,508
Cost of mining, transportation, stamping and taxes per ton of rock	$1.45	$1.53	$2.02	$2.14
Pounds of refined copper produced	9,342,106	12,412,111	13,480,921	15,442,508
Pounds refined copper per ton of rock treated	13.7	13.4	14.6	15.9

good for 1918. The total cost per ton milled was $2.40. Since 1913, $1,950,000 has been paid from about 58,000,000 pounds of copper, some 3.5 cents per pound. An equal amount was added to quick assets.

	1915	1916	1917	1918
Rock hoisted, tons	799,890	1,144,310	1,200,975	1,187,486
Rock house discard, tons	119,620	218,891	278,815	212,978
Percentage of discard	15.0	19.1	23.2	17.9

Osceola Consolidated.—The Osceola Cons. Mining Company works some large amygdaloid mines near the Calumet & Hecla.

ABSTRACT OF THE REPORTS OF THE OSCEOLA MINING CO.

The following table gives the comparative results for 1906, 1907 and 1908.

	1906	1907	1908
Tons rock stamped	1,016,240	811,603	1,241,400
Pounds mineral obtained	24,227,281	18,607,747	26,912,944
Percentage refined copper in mineral	76.725	75.962	78.961
Pounds refined copper per ton of rock stamped	18.3	17.4	17.1
Product fine copper	18,588,451 lb.	14,134,753 lb.	21,250,794 lb.
Cost per pound at mine, excluding construction	8.73 cents	10.59 cents	8.74 cents
Cost per pound construction	0.84 cents	0.60 cents	0.69 cents
Cost per pound of smelting, freights, eastern expenses, commissions, and all other charges	1.32 cents	1.25 cents	1.10 cents
Total cost per pound of refined copper	10.89 cents	12.44 cents	10.53 cents
Cost of mining and stamping per ton of rock stamped	$1.60	$1.84	$1.50
Gross cost of stamping per ton	16.39 cents	17.47 cents	15.78 cents
Net cost of stamping per ton after deducting profit on custom rock	13.83 cents	11.71 cents	13.34 cents

From the above, it appears that the total costs per ton for 1908 were $1.80 as compared with $2.16 in 1907, and $1.99 in 1906. This rise and fall of cost was an experience the company shared with nearly all other mining companies during this period.

The reports state that the old Osceola mine shows large reserves of copper towards the south end, the northerly shafts being more nearly worked out. At the North Kearsarge mine No. 1 shaft was damaged by fire in September, 1906, and repaired at a cost of $36,950. This was

charged to operating expenses. The report contains little additional information of interest.

The total dividends to date are $7,612,550. Dividends since the beginning of 1901 have been $3,942,150 from an output of 136,584,911 lb., equal to a trifle less than 3 cents a pound. Lake copper in the same period averaged 15.57 cents in price. It appears from this that the copper has averaged some 12.5 cents in cost, including everything.

The company has been absorbed by the Calumet & Hecla.

At this mine the proportion of development work to ore treated is extraordinarily small. For four years it was only 1 ft. to 200 tons. This mine paid $17,371,000 in dividends in forty years 1878–1918 inclusive.

COMPARATIVE RESULTS FOR THE FOUR YEARS

	1910	1911	1912	1913
Tons of rock treated	1,217,720	1,246,596	1,246,557	735,044
Cost of mining, transportation, stamping and taxes per ton of rock	$1.28	*$1.14	†$1.23	‡$1.60
Pounds of mineral obtained	25,669,913	24,452,912	24,282,312	14,945,645
Pounds of refined copper produced	19,346,566	18,388,193	18,413,387	11,325,010
Per cent of refined copper in mineral	75.367	75.198	75.830	75.775
Pounds refined copper per ton rock treated	15.9	14.8	14.8	15.4
Cost per pound:				
Expenses at mine	8.04 c.	7.73 c.	8.34 c.	10.39 c.
Construction	0.35 c.	0.49 c.	0.95 c.	0.77 c.
Smelting, freight, commissions, eastern office, etc.	0.98 c.	1.06 c.	1.07 c.	1.14 c.
Total cost per pound refined copper	9.37 c.	9.28 c.	10.36 c.	12.30 c.

COMPARATIVE RESULTS FOR THE PAST FOUR YEARS

	1915	1916	1917	1918
Tons of rock treated	1,361,089	1,284,681	1,237,805	1,194,967
Cost of mining, transportation, stamping and taxes per ton of rock	$1.18	$1.36	$1.63	$1.78
Pounds of refined copper produced	19,731,472	19,586,501	16,084,958	15,919,647
Pounds refined copper per ton rock treated	14.5	15.2	13.0	13.3

Baltic Lode (1908).—The second type of amygdaloid deposits, represented by the Baltic, Trimountain, and Champion mines of the Copper Range Consolidated Company, presents a more difficult problem in operating. The Baltic lode has a dip of about 70°. Its hanging wall is insecure so that it will not stand for any considerable area without support. Moreover, the vein is wide, sometimes as much as 50 ft., and the vein stuff has more the appearance of trap than the ordinary amygdaloid. The great width of the vein would in many cases make the leaving of pillars to support the hanging wall a very expensive and doubtful expedient.

Mining on this lode by the ordinary methods used for amygdaloid deposits was a failure. The whole vein had to be mined in order to find the copper which was scattered somewhat irregularly through the mass; but the whole vein proved to be too low grade to pay. It would yield only about 14 lb. copper to the ton. F. W. Denton solved the problem approximately as follows: The vein as a whole yielded in the mill 14 lb. copper and probably contained six additional pounds of copper that were lost in the milling process. By picking out waste or low-grade ore in the mine it was found that 40 per cent. that would run no better than the mill tailings could be rejected. This selection yielded the following results: 100 tons mined contained 2000 lb. copper; 40 tons were rejected containing 240 lb., this left 60 tons of material containing 1760 lb. of copper or 29 lb. to the ton. This when sent to the mill and treated with a loss of 7 lb. in the tailings yielded 22 lb. per ton milled as against 14 lb. obtained before.

Logically, this process means additional expense as follows: 100 tons of rock would have to be broken and only 60 tons realized. If to break the whole vein cost 40 cents a ton, the breaking of the 60 tons recovered must cost 67 cents per ton. This represents about the measure of additional expense involved in the selection process. The coarse waste picked out underground can be piled back as easily as it can be shoveled into cars by the ordinary process and taken to the shaft. Indeed, it is possible that an actual saving is effected in tramming by the use of this system because it is easier to get the rock into a chute than it is to shovel it into a car, and the tramming of the rock from the chute to the shaft is practically as cheap as it would be to push the cars to the shaft after they were loaded by hand.

Peculiarities of Sorting and Filling Method.—This method of filling the stopes by rock sorted from the vein itself is a novelty in Lake Superior though not in the mines of the West. Since it was developed independently by Mr. Denton, it resulted in one or two points of practice different from that employed anywhere else.

The rock sorted from the vein is hard and rough, and this fact has been taken advantage of in building up stone walls on the levels instead of using timbered drifts. These stone walls are covered with large timbers and lagging and then the whole thing is covered with the waste

filling. It is found that stone walls resist the pressure of the accumulating filling very much better than any timber, and in fact maintain themselves in perfect condition as long as they are required. The mill holes leading through the waste to the working faces at the top instead of being built of wooden cribbing are circular wells laid in stone. In building the walls on the main levels and in the mill holes, advantage has been taken of the presence of Italian and Austrian miners who usually have had expeience in laying stone walls in their own country. The total result is a very pretty adaptation of methods to the natural conditions.

The results in dollars and cents obtained by this method are all, and rather more, than could be expected. As compared with the Wolverine we find that in 1905 the underground costs at the Baltic were $1.04 a ton, and in 1906, $1.06 a ton, against $0.93 and $0.98, respectively, at the Wolverine, a difference of about 10 cents a ton as against the 27 cents increase that we might have expected. The Copper Range mines are, however, less than 1000 ft. deep, while the Wolverine will average more than 2000 ft.; so that the former gets some advantage in costs on this account.

There are certain advantages in the sorting and filling system over and above mere availability. These are: (1) The security of the mine; (2) the fact that no pillars need be left for any reason, unless, indeed, the shafts are sunk in the vein in which case it is always necessary to leave some ground on each side of the shaft; (3) the system completely solves the question of exploring the vein for its copper contents enough ground can always be taken to expose stringers and bunches running into the walls.

Costs at Copper Range Mines.—Outside of the operations in the mine itself, the Copper Range Company does its business much as other amygdaloid mines do; whatever further economies it achieves are entirely due to mechanical reasons and the volume of material handled and not to difference in the method. The accompanying table gives the results obtained in recent years.

COSTS OF MINES OF THE COPPER RANGE CONSOLIDATED COMPANY 1906

	Baltic	Champion	Trimountain
Tons stamped	649,932	671,785	506,942
	Per ton	Per ton	Per ton
Superintendence and labor	$0.79	$.086	$1.05
Rock house	0.07	0.10	0.08
Hoisting	0.06	0.05	0.09
Power drills	0.06	0.07	0.07
Timber and supplies	0.15	0.16	0.14
Surface costs	0.06	0.08	0.07
Transportation to mill	0.17	0.14	0.11
Stamping	0.18	0.22	0.21
Smelting, refining, and marketing	0.25	0.32	0.23
Total operating	1.79	2.00	2.05
Taxes	0.70	0.09	0.08
Construction, estimated average	0.10	0.10	0.10
Average current costs	1.96	2.19	2.23
10,000,000 tons to be mined in 26 years from time of investment at 5 per cent. interest and 2 per cent. amortization	0.15	0.27	0.22
	$2.11	$2.46	$2.45
Recent yield copper per ton	22 lb.	25 lb.	19 lb.
Current cost copper per lb	9 cents	8¾ cents	11.7 cents
Cost of copper, per pound, complete	9½ cents	9¾ cents	12⅞ cents

	Pounds	Cost	Per pound cents
Baltic	63,211,963	$5,808,000	9.19
Champion	66,938,611	6,512,000	9.74
Trimountain	34,210,014	4,172,000	12.2
	164,360,588	$16,492,000	10.00

It seems proper to say that 10 cents per pound is the true dividend cost. Figuring on averages these mines would appear to be able to produce 41,000,000 lb. a year at a profit of 5.5 cents. The Copper Range Company owns one-half the stock of the Champion and practically all the stock of the other mines, together with the Copper Range Railroad. The railroad does not earn much. We may estimate the total average earnings of the company at 15½-cent copper at $1,750,000 per year, equal to some $4.55 per share. Conceding that this average can be maintained for twenty years we may estimate a value of $57 a share.

COPPER RANGE COMPANY

Comparative Statement

(Baltic, Trimountain and one-half Champion combined.)

	1918	Average for ten years, 1909 to 1918 inclusive
Tons of rock stamped	792,151	1,161,775
Pounds of refined copper produced	26,623,940	29,483,340
Pounds of refined copper per ton stamped	33.61	25.38
Cost of copper per pound	$0.1446	$0.1033
Price received per pound	0.2476	0.1824
Profit per pound	0.1030	0.0791
Mining expense, smelting, freight, marketing copper, etc	$3,849,216.38	$3,045,764.49
Net earnings Copper Range Company	2,895,615.28	2,333,045.60

Dividends paid in 1905	$1,536,086.00
Dividends paid in 1906	2,304,810.00
Dividends paid in 1907	2,304,810.00
Dividends paid in 1908	1,536,740.00
Dividends paid in 1909	1,536,930.00
Dividends paid in 1910	1,537,340.00
Dividends paid in 1911	1,357,104.00
Dividends paid in 1912	788,428.50
Dividends paid in 1913	1,084,498.00
Dividends paid in 1915	1,182,003.00
Dividends paid in 1916	3,941,648.00
Dividends paid in 1917	3,943,912.50
Dividends paid in 1918	2,366,394.00
Total dividends paid to December 31, 1918	$25,420,704.00

CHAMPION COPPER COMPANY

Statement of Receipts and Expenditures from Date of Organization to December 31, 1918.

Receipts

Capital stock	$ 2,500,000.00
From sale of copper (1902) 4,165,784 lb. at 11.82 c	492,553.36
From sale of copper (1903) 10,565,147 lb. at 13.37c	1,412,711.43
From sale of copper (1904) 12,212,954 lb. at 13.02 c	1,591,109.71
From sale of copper (1905) 15,707,426 lb. at 15.56 c	2,444,554.91
From sale of copper (1906) 16,954,986 lb. at 19.06 c	3,231,328.71
From sale of copper (1907) 16,489,436 lb. at 17.28 c	2,848,838.41
From sale of copper (1908) 17,786,763 lb. at 13.39 c	2,381,137.30
From sale of copper (1909) 18,005,071 lb. at 13.00 c	2,339,361.62
From sale of copper (1910) 19,224,174 lb. at 12.74 c	2,447,844.73
From sale of copper (1911) 15,639,426 lb. at 12.54 c	1,960,758.13
From sale of copper (1912) 17,225,508 lb. at 16.16 c	2,782,457.60
From sale of copper (1913) 12,080,594 lb. at 14.89 c	1,798,984.15
From sale of copper (1914) 15,807,206 lb. at 13.38 c	2,114,468.18
From sale of copper (1915) 33,407,599 lb. at 17.40 c	6,814,279.21

From sale of copper (1916) 33,601, 136 lb. at 25.28 c		8,494,367.18
From sale of copper (1917) 27,550,343 lb. at 28.735 c		7,916,569.27
From sale of copper (1918) 21,748,514 lb. at 24.757 c		5,384,208.35
Total copper production, 308,172,067 lb.		$57,955,532.25
To end of 1915............225,272,074		$33,660,338
Average price 15 cents.		

Expenditures

Real estate (Champion location)	$1,025,000.00	
Real estate (lands since purchased)	14,095.28	
	$1,039,095.28	
Net expenditures for construction and equipment, mining operations, smelting and marketing copper taxes, and incidentals	30,866,413.66	31,905,508.94
Net balance of receipts		$26,050,023.31
Dividends paid in 1903	$300,000.00	
Dividends paid in 1904	200,000.00	
Dividends paid in 1905	1,000,000.00	
Dividends paid in 1906	1,200,000.00	
Dividends paid in 1907	1,000,000.00	
Dividends paid in 1908	500,000.00	
Dividends paid in 1909	800,000.00	
Dividends paid in 1910	900,000.00	
Dividends paid in 1911	500,000.00	
Dividends paid in 1912	1,100,000.00	
Dividends paid in 1913	900,000.00	
Dividends paid in 1915	3,100,000.00	
Dividends paid in 1916	6,014,540.96	
Dividends paid in 1917	4,480,000.00	
Dividends paid in 1918	1,975,720.00	23,970,260.96
Excess of receipts over expenditures		$2,079,762.35

Dividends to end of 1915, $11,500,000 equal to 5.11 cents per pound

TRIMOUNTAIN MINING COMPANY

Statement of Receipts and Expenditures from Date of Organization to December, 31, 1918

Receipts

Capital stock		$2,000,000.00
From sale of copper (1902)	5,730,633 lb.	712,959.76
From sale of copper (1903)	9,237,051 lb	1,186,547.57
From sale of copper (1904)	10,211,230 lb	1,396,188.30
From sale of copper (1905)	10,476,462 lb	1,620,893.76
From sale of copper (1906)	9,507,933 lb	1,791,714.68
From sale of copper (1907)	8,190,711 lb	1,415,088.48
From sale of copper (1908)	6,034,908 lb	807,901.07
From sale of copper (1909)	5,282,404 lb	686,331.95
From sale of copper (1910)	5,694,868 lb	725,138.66
From sale of copper (1911)	6,120,417 lb	767,332.52
From sale of copper (1912)	6,980,713 lb	1,127,603.33
From sale of copper (1913)	4,990,938 lb	743,226.51

From sale of copper (1914)	5,048,306 lb	675,293.75
From sale of copper (1915)	8,302,896 lb	1,445,041.27
From sale of copper (1916)	8,720,558 lb	2,204,557.06
From sale of copper (1917)	6,278,097 lb	1,804,006.21
From sale of copper (1918)	5,343,586 lb	1,322,894.09
Total copper production,	122,151,711 lb	
Balance of interest account		216,556.33
		$22,649,275.30
Last 3 years	20,342,241	5,331,457
	101,809,470	17,317,818

Receipts from copper sales to end of 1915, $15,101,000 from 101,809,000 pounds, equal to 14.84 cents per pound.

Expenditures

Real estate (Trimountain location)	$800,000.00	
Real estate (land since purchased)	3,000.00	
	803,000.00	
Net expenditures for construction and equipment, mining operations, smelting and marketing copper, taxes, and incidentals	16,768,453.88	$17,571,453.88
Net balance of receipts		$5,077,821.42
Dividends paid in 1903	$300,000.00	
Dividends paid in 1908	500,000.00	
Dividends paid in 1910	150,000.00	
Dividends paid in 1912	300,000.00	
Dividends paid in 1913	200,000.00	
Dividends paid in 1918	500,000.00	1,950,000.00
Excess of receipts over expenditures		$3,127,821.42

Dividends to end of 1915 from 101,809,000 pounds, $1,450,000, equal to 1.42 cents per pound.

From these statements, assuming that the period up to the end of 1915 represents normal competitive conditions, we may deduce that the average price of copper for the Champion was 15 cents a pound and the profits for this 5.11 cents, leaving a cost of 9.89 cents.

Similarly for the Trimountain we find that the price of copper was 14.84 cents the profits 1.42 cents and the cost 13.42 cents. The results of the succeeding years, as in most other cases, do not correspond with these figures. From 1913 to 1918 the Trimountain paid no dividends, from which we may suppose that it is normally unprofitable. It took three years of war prices to enable it to pay anything.

The Baltic, also, is probably a modest earner. No detailed report is issued for it for 1918, but the cost of producing copper is put down at 15.07 cents; that of Trimountain being 18.42 cents, and of Champion 11.92 cents. The average of these costs, considering the general conditions, is undoubtedly good. On a return to pre-war prices the Champion would be producing for about 7 cents a pound.

Tamarack and Calumet & Hecla (1908).—The third type of Lake Superior copper mines is represented by the Tamarack and the Calumet & Hecla. The record of these properties shows very clearly that the conglomerate is a more difficult and expensive problem than the amygdaloid. The deposit has the advantages of remarkable uniformity and continuity; but as compared with the amygdaloid, the conglomerate has three features that substantially increase the cost of working: (1) The richness of the ore has averaged 2½ times as great as that of the characteristic amygdaloid; consequently the cost for smelting has been 2½ times as great, and this fact has meant an increased cost of not far from 50 cents a ton. (2) The conglomerate is much harder, tougher, and more difficult to handle. It breaks in rough, ugly chunks which wear out the tram cars, bin linings, and stamp shoes very rapidly. Its greater hardness is reflected by the fact that the mills will handle 40 per cent. more amygdaloid than of conglomerate. This characteristic in itself is probably sufficient to add in the neighborhood of 20 cents a ton to the cost of handling, breaking, tramming, crushing, and milling this ore. (3) The hanging wall is loose and the mines need constant and expensive timbering. This item has added from 25 to 75 cents a ton to the cost.

The total of these increased costs may be reckoned at, in round numbers, $1.20 a ton. The above figures have reference to the average conglomerate ore as mined to date which has contained not less than 55 lb. copper to the ton. At present[1] the Calumet & Hecla is yielding only 42 lb. a ton while the Tamarack is yielding only 23 lb. On the present basis, therefore, the smelting costs are somewhat lower than they would be for an average of this class.

Results and Costs at the Tamarack.—Up to July 1, 1893, the Tamarack mine had produced 84,000,000 lb. copper from 1,400,000 tons of rock, an average of 60 lb. per ton. The cost for operating was $5,816,083, or $4.15 a ton. Construction on the original mine from which this ore came was 69 cents a ton additional. The total cost had, therefore, averaged $4.80 per ton or 8 cents per pound copper. In 1892–3, 345,925 tons were stamped, yielding 46.43 lb. per ton. The costs were:

Underground mining	$1.69
Rock house, surface and stamping	0.77
Smelting	0.82
Total operating	$3.28
Construction on old mine	0.04
Construction on new shafts	2.14
Total	$5.46

[1] January, 1908. The yield has since fallen below 35 lbs.

By 1899 the costs were:

Total operating	$3.50
Construction	0.63
Total	$4.13

By 1904 the costs had become

Mining and stamping	$2.42
Smelting and general	0.61
Total	$3.03

Of late years a good deal of amygdaloid has been mined.

Since 1904 the operations on the Tamarack have been very much interfered with by a serious underground fire and other difficulties and delays. It is probable that the above figures give a fair idea of the results obtained. The item of construction has been very heavy indeed. It is accounted for by the sinking and equipping of five very deep and expensive shafts. It appears that up to 1899 the output of the Tamarack had been about 4,400,000 tons, produced at a total cost of $17,600,000 ,or $4 a ton. The resulting product was 195,000,000 lb. copper, or an average of about 44.3 lb. to the ton, the cost of fine copper being about 9 cents a pound.

Calumet & Hecla.—The Calumet & Hecla has been a rich mine and its costs may have been somewhat higher than were strictly necessary. For the last ten years it seems that the costs have averaged a little over $4 a ton, but since the company issues no detailed reports, it is possible to make only an approximation. The cost does not appear at a disadvantage compared with the Tamarack, for while the Tamarack ores averaged about 44 lb. copper per ton, those of the Calumet & Hecla have averaged 50 lb.; and while it is true that the Tamarack has expended large sums on new construction and development, it must not be forgotten that the Calumet & Hecla has done the same thing during the same periods. At present the Calumet & Hecla is mining an increasing proportion of amygdaloid from the neighboring Osceola and Kearsarge lodes to the eastward of the conglomerate.

It appears that the conglomerate workings as compared with a representative amygdaloid mine like the Wolverine would appear somewhat as follows:

Underground factors making for increased cost are: the very great depth, averaging more than 4000 ft. vertically; the considerable heat, averaging about 80°; the necessity of timbering, which in itself accounts for at least 30 cents a ton; the hard, angular character of the ore which renders shoveling, tramming and handling more difficult and expensive; and finally, the difficulty of maintaining the deep inclined shafts under a weak hanging wall.

It does not seem unreasonable to appraise these factors at 50 cents a ton, at least, excess cost over that of the amygdaloid mine of moderate depth. The cost of milling the ore should be approximately 15 cents a

ton greater; while the cost of smelting 42 lb. fine copper per ton as against 22 lb. should be 25 cents more. To sum up it appears that mining costs representing the two types should compare about as follows:

	Amygdaloid	Conglomerate
Underground expense and rock house	$1.10	$1.60
Transportation and milling	0.40	0.55
General expense	0.22	0.22
Smelting, refining and marketing	0.25	0.50
Total	$1.97	$2.87

The above costs omit the item of construction which has always been a very large item with these mines. It is safe to say that the Calumet & Hecla has spent 40 cents a ton throughout its career on its plant for construction.

The costs of Calumet & Hecla on Osceola amygdaloid for 1910 are reported as follows:

Mining	$0.9993	
Hoisting	0.101	$1.2039
Rock house	0.1336	
Transportation	0.0844	
Milling	0.2631	0.3655
Other	0.018	
Total	$1.5694	$1.5694
Assuming that the output is 18 lb. copper per ton, we must add for smelting, refining, and marketing		0.22
Add also for general expense, same as for Wolverine		0.22
Total		$2.0094

Calumet & Hecla Records.—Until 1908 this great company had been extremely guarded in giving out information about its operating results. In order to form an idea of its costs it was necessary to compile such scraps of information as could be gleaned from a series of reports and make such deductions as seemed warranted. This state of affairs now seems partly to be a thing of the past. A legal controversy over the right of the Calumet & Hecla to control and manage the Osceola Consolidated Mining Company resulted in the disclosure of most of the essential facts regarding the former company's business condition. In the report for 1908 President Agassiz frankly gives these facts and it is to be presumed that more will be forthcoming in succeeding reports. The following summary shows the facts that may be had from the reports in the past eleven years:

Year	Tons fine copper	Price cts. per lb.	Dividends	Spent in purchase new property	Balance of quick assets
1897–8........	41,960	....	$4,000,000	....	$6,558,456
1898–9........	43,879	....	7,000,000	....	4,398,544
1899–00.......	44,548	...	8,000,000	....	4,260,858
1900–01.......	37,933	....	6,500,000	....	2,168,130 fire
1901–02.......	42,462	....	4,000,000	....	3,592,779
1902–03.......	42,216	....	2,000,000	....	6,557,023
1903–04.......	41,612	....	4,000,000	....	6,583,038
1904–05.......	43,090	....	4,500,000	42,000 acres timber land	7,144,000
1905–06.......	43,652	....	5,000,000	$184,859	10,629,819
1906–07.......	46,297	....	7,500,000	9,223,395	7,028,942
1907–08.......	43,264	....	5,000,000	....	4,700,755
	470,913	15.2	$57,500,000	$9,408,254	1,857,701 decrease
			1,857,701		
Total cash earnings...........			55,642,299		
Add investments, partial only..			9,408,252		
			65,050,551		

1888..............	Milled 814,000 tons for 50,295,721 lb. copper—61½ lb. per ton.
1897–8............	Cost $4.05 per ton milled.
1899–00...........	Pounds copper per ton 59.93, 1,464,697 tons milled.
1902..............	Pounds copper per ton 52.44.
1904–5............	Milled 74,235 tons Osceola amygdaloid 22 lb. per ton.
1906..............	Milled in March 27,018 Osceola amygdaloid.
1905–6............	Milled 1,900,000 tons for 87,304,000 lb.—45.9 lbs. per ton.
1906–7............	Milled 1,900,000 tons Calumet conglomerate. 350,000 tons Osceola amygdaloid for 6,892,548 lb. 2,250,000 altogether for 92,584,000 lb. = 41 lb. per ton.
1907–8............	Milled 1,894,176 tons conglomerate averaging 39.68 lb. per ton. 603,891 tons Osceola amygdaloid yielding 11,145,220 lb. or 18.4 lb. per ton.

In the year ending April 30, 1908, the "Product" of refined copper is stated at 78,980,466 lb. There is some reason to believe that this means "Product sold." It is also reported that the company was constantly in the market, selling copper during the declining prices of 1907. If this is so, it must have realized practically the quotational average for the period, or 16.6 cents. On this basis the receipts for the year were about $13,000,000. The dividends were $5,000,000, leaving a balance of $8,100,000.

There is no mention made of any considerable outside investments made during the year except the purchase of 50,100 shares in the Gratiot Mining Company. What the price was is not stated. Some explorations were also carried on in various places. Under these circumstances an

estimate of the cost of mining is nothing but a guess. However, I will venture the guess. In 1907 the dividends were $7,500,000. In addition $9,223,000 were expended in the purchase of property, but in so doing the balance of assets was diminished $3,600,000, leaving a net expenditure of about $5,600,000 from the proceeds of that year's business. The total profits then must have been about $13,100,000. The revenue from copper sales for that year was approximately $20,400,000. Deducting the profits we have left the costs, about $7,300,000. In that year 350,000 tons of Osceola amygdaloid was mined at an expense of $700,000. Deducting this we have $6,600,000 as the cost of mining 1,900,000 tons of conglomerate, $3.47 a ton.

In the following year a cut of 10 per cent. was made in wages, but not until the latter part of the fiscal year. The effect of this probably was so diminished costs by 5 per cent. for the whole fiscal year.

For 1908, then, I place the cost of mining the conglomerate at $3.30 and for the Osceola amygdaloid at $1.90. The total cost then would be:

Conglomerate, 1,894,176 tons at $3.30	$6,230,000
Amygdaloid, 603,891 tons at $1.80	1,150,000
Total	$7,380,000
Estimated cost of outside work and investments	720,000
	$8,100,000

These figures should be read in the light of the following remarks by President Agassiz in the report for 1908:

"In several of the previous annual reports the attention of the stockholders has been called to the unsatisfactory character of the conglomerate below the 57th level in the northern part of the mine. In 1900, the year before Mr. McNaughton became General Manager of the Company, the conglomerate yielded about 59.93 lb. of copper to the ton. I regret to state that since then this percentage has annually been diminishing. In 1902 it has fallen to 52.44 lb. to the ton. For the past fiscal year its yield was 39.68 lb. To maintain our product we have stamped an additional amount of conglomerate rock in addition to the amygdaloid rock mined from the Osceola lode, which has been increased from 74,235 tons in 1905 to 603,891 tons in 1907–08. The amount of conglomerate stamped has gradually increased from 1,464,697 tons in 1900 to 1,894,176 tons in 1907–08. Thus in 1907–08 eating into the available conglomerate at a rate far in excess of that we had been accustomed to consider the normal additional source of copper supply to replace that obtained from the waning conglomerate lode. We anticipate a still further reduction in the percentage. During the last five years the cost per ton of rock has been greatly reduced, partially offsetting the decrease in the copper contents of the rock."

It will be seen, by a study of the table given above, that the average cost of copper for eleven years must have been 8.16 cents a pound. In 1898 it probably was 7 cents for a safe average and in 1908 was about 9 cents.

Calumet and Hecla Conglomerate mine in later years.

By comparison with these deductions the actual record as given in the reports for recent years is interesting.

The report for 1918 also shows the depths reached by the different shafts. If I understand it correctly, Tamarack shaft No. 3 had reached a vertical depth of about 5800 feet.

Up to the end of 1918, the Calumet and Hecla had been able to pay in dividends from the output of its original mines, about $140,000,000. from about 2,700,000,000 pounds of copper, some 5.2 cents a pound.

Conglomerate Lode

The comparative results of operations for the four years are as follows:

	Year ending December 31			
	1910	1911	1912	1913
Tons of rock treated	1,950,040	1,924,480	1,746,960	1,175,259
Mine cost per ton of rock (excluding construction)	$2.13	$2.07	$2.23	$2.99
Pounds of copper produced	58,739,509	58,469,399	51,935,245	32,731,768
Pounds of copper per ton of rock	30.12	30.38	28.73	27.85
Total cost per pound of copper produced	8.55 c.	8.25 c.	8.87 c.	12.67 c.
Shaft sinking	464 feet	546 feet	523 feet	172.5 feet
Drifting	9,215 feet	8,613 feet	10,048 feet	5,929 feet
Crosscuts and foot-wall drifts	625 feet	201 feet	614 feet	o feet

The operating shafts on this lode have attained the following depths:

Calumet Nos. 5 and 6	6155.0 feet, to boundary to 60th level.
Calumet No. 4	7995.0 feet to boundary to 81st level.
Calumet No. 2	6186.0 feet sinking permanently discontinued at 63d level.
Slope shaft	1588.0 feet below 57th level or 185 feet under 66th level
Hecla No. 6	7857.5 feet under 79th level.
Hecla No. 7	7876.5 feet 39 feet under 80th level.
South Hecla No. 8	6102.0 feet sinking permanently discontinued at 63d level.
South Hecla Nos. 9 and 19	7823.5 feet 34 feet under 80th level

CONGLOMERATE LODE

The comparative results of operations for the past four years are as follows:

	Year ending December 31			
	1915	1916	1917	1918
Tons of rock treated	1,739,984	1,727,794	1,751,621	1,547,603
Mine cost per ton of rock (excluding construction)	$2.13	$2.63	$3 26	$4.09
Pounds of copper produced	51,738,588	51,785,016	50,415,860	43,329,816
Pounds of copper per ton of rock	29.74	29.97	28.78	28.00
Shaft sinking	201 feet	0 feet	0 feet	33 feet
Drifting	5,22 feet	5,142 feet	2,942 feet	7,149 feet
Crosscuts and foot-wall drifts	0 feet	0 feet	0 feet feet	3,659 feet

The operating shafts on this lode have attained the following depths:

Calumet Nos. 5 and 6... 6,155.0 feet, to boundary to 60th level.
Calumet No. 4.......... 7,995.0 feet to boundary to 81st level.
Calumet No. 2.......... 6,186.0 feet sinking permanently discontinued at 63d level.
Slope shaft.............. 1,588.0 feet below 57th level or 185 feet under 66th level.
Hecla No. 6............ 7,874.6 feet, 32.7 feet under 80th level.
Hecla No. 7............ 7,977 feet, 40 feet under 81st level.
South Hecla No. 8....... 6,102.0 feet, sinking permanently discontinued at 6d3 level
South Helca Nos. 9 and 10 8,132.7 feet, 152 feet under 83d level.
Red Jacket Shaft....... 4,900 feet, 100 feet under 81st level.
Tamarack No. 3.......... 29.5 feet below the 18th level, 5,253 feet from surface.
Tamarack No. 3 (inclined) 8 feet below the 24th level, 616 feet below the 18th level.
Tamarack No. 5........... 147 feet below the 40th level, 5,308.5 feet from surface.

about 70 per cent. metal. This mineral is then smelted at plants situated along the shores of Portage lake, an inlet of Lake Superior. The smelting and refining are done by a single process; and ingot copper is produced that needs no further refining, the copper being exceptionally pure and commanding a higher price than any other in the market.

CHAPTER XV

BISBEE

Geologic speculations—The Permian revolution—Geography of Pennsylvanian time—Geography of Permian time—The preservation of mineralized batholiths—The Permian mountain range of California—Economic conditions of Bisbee—Early ideas of Dr. James Douglas—Present state of the business—Calumet and Arizona—History—Smelteries at Douglas—Economic units—Growth of Phelps Dodge and Calumet and Arizona—Comparisons of ten years—General tendencies—Pursuit of economy—Analysis of mining costs of the Copper Queen.

Various references have been made in other chapters to the cycles of change that have occurred upon the earth's crust, (see chapters on coal, the Jerome district, the Porphyry coppers). It has been explained that coal is deposited toward the end of long periods of base-leveling; that many or most of the valuable ore deposits are incident to intervening mountain building efforts; that the principal fissure veins and disseminated sulphide deposits have identical origin; that erosion is a necessary factor in exposing them; and an important factor, through the process of secondary enrichment, in determining their economic value. It seems worth while to dwell a little further upon the observations upon which these conclusions rest, and to bring out if possible a few more points about the relation of ore-deposits to broad geologic processes. It is not improbable that very much more may be learned about the distribution of valuable deposits by analyzing the geography of past epochs of world history. For this line of thought the ore deposits of Bisbee will serve as an illustration.

It is a rational inference, or at least an entertaining speculation, that these deposits originated during the Permian "revolution." They occur in Paleozoic rocks, some of which are as late as Pennsylvanian; but according to the geologists of the Phelps Dodge Corporation, these rocks are not only unconformable with the next sedimentary series of the locality, the Comanche or Lower Cretaceous, but had been partially uncovered and extensively oxidized during an intervening period. It is true that there is a possibility that the mineralization took place in Triassic or Jurassic times, but on the whole it seems more likely that during those periods this part of the continent was elevated and was undergoing the erosion just referred to; that the mountain building and batholithic action of which these deposits were an incident, had occurred somewhat earlier. Various facts may be patched together to support this conclusion as well as to give some inkling of the geography of the times.

During the late Carboniferous, or Pennsylvanian, time, an extensive clear water sea covered a very large part of western North America and in it were deposited enormous beds of limestone which may be found in every state west of Louisiana and Minnesota, with the possible exception of Washington. Similar marine limestones are found also to the south in Mexico and to the north in western Canada. Swampy lowlands, occasionally flooded by shallow invasions of the sea, extended in a vast plain from central Oklahoma to the Hudson river, and even, perhaps, through Massachusetts to Nova Scotia and beyond. It appears then that the shore of the Pacific ran prevailingly from the present Gulf of Mexico northwestwardly through the heart of the Great Plains into northwestern Canada. One would suppose that in the vast area between this shore line and the present Pacific coast there must have been some islands,

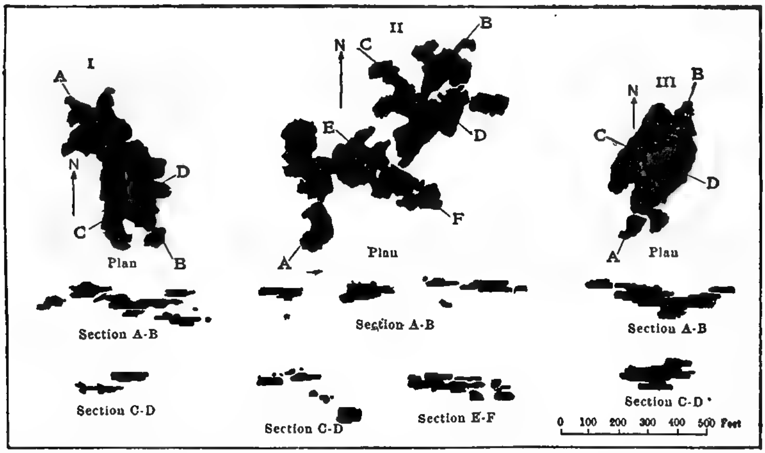


Fig. 5.—Sketch showing arrangement of ore bodies, in Bisbee, Arizona where 1 foot of development work opens 11 tons of ore.

great or small, but so far as I can learn, the position of any such islands has not yet been made out. It thus seems to be a fair statement that the great plains on which the Pennsylvanian coal was formed, now far within the drainage of the Atlantic, at that time debouched upon the Pacific Ocean. The main land mass at that time was undoubtedly the northeastern half of the present continent to which perhaps there were then attached large areas toward Greenland and Iceland and even Northern Europe, that are now partially flooded by the Atlantic. It is also probable that the land itself was comparatively flat, having been maturely eroded into a very moderate relief.

These conditions in the opinion of geologists are sufficient, or nearly sufficient, to explain the climate of Pennsylvanian times, which apparently was mild, moist and equable over most of the world. Perhaps

the area of sea as compared to land was considerably greater than it is today. This, it is supposed, might be brought about by the long continued erosion, by which a considerable portion of the continents had actually been swept into the sea, and at the same time the sea level had been raised appreciably simply by the displacement of the water of the ocean basins by sediments. Of course if the solid crust of the earth should be reduced to a dead level, that is if the inequalities were to be removed, there would be neither continents nor islands, but a universal ocean about two miles deep. It is thought that the progress of base-leveling might bring about some portion of such a result.

However this may be, it is at least significant that changes of climate seem to coincide with changes of geography. Both occurred during the Permian. In the Rocky mountain area the sea not only disappeared throughout, but the thick masses of sediments which had formed on its floor were broken through by the upthrust of fault blocks and the crystalline rocks (granites, etc.,) of the underlying crusts were exposed along many an excarpment. To mention well known localities, evidences of this may be seen plainly at the Garden of the Gods, near Colorado Springs and at numerous other localities easily visited along the Front Range all the way from Cheyenne to Albuquerque. If one examines the red conglomerates in the Garden of the Gods, he finds that some of them are almost pure granitic talus, which crumbles in the fingers and is patently derived from the Pike's Peak granite. Two handfuls of such gravel, one from the Permian red beds, the other from a stream that washes it down in 1919, are absolutely indistinguishable.

Other evidences of an abrupt change of climate, are far from lacking. In central Kansas great beds of salt are found in a wide area in Permian rocks, representing the drying up of an extensive sea—a sure proof of desert climate. Such an occurence may be explained by the emergence of the new mountain barrier just referred to, just as the drying of Great Salt Lake of our day is explained by the presence of the Sierra Nevada. In other parts of the world intense refrigeration took place. Continental glaciers on an immense scale were developed in south central Asia, in South America, South Africa and Australia. The Permian was a "revolution" indeed.

It is in such events that many, if not most, ore-deposits originate. The upthrust of mountain chains and plateaus, the deepening of oceanic troughs must be due to the exhaustion of the ties that had been maintaining the stability of the earth's crust; or conversely, during a long period of quiesence strains accumulate in the sub-crust. Such strains are expressed either in heat or movement or in both; the longer they accumulate, the more heat and movement there will be to dispose of. Naturally this is a matter of speculation, but a review of geologic history as well as a study of the principal areas of mineralization, tends to urge it upon one's

imagination. It seems, moreover, worth noting that the escape of molten magmas into the upper crust is especially favorable to the formation of ore deposits when that surface has been covered by a thick accumulation of sediments. It is supposed that the chief mineralizing agent is superheated water thrown off by the cooling and crystallization of extensive magmas. If such waters escape freely to the surface, the mineralization also will escape in the air. If, however, the magmas force their way only into the lower portions of the comparatively cold crust, say into the lower strata of great sedimentary formations, the waters from them will be cooled by, and their mineral contents precipitated in those rocks. Mineralization takes place in or around the *upper portions* of the peripheral surface of the cooling magmas, or batholiths.

Several consequences would follow. The batholithic action is a part of the formation of mountains. Mountains are subject to intensified erosion. If the domes of the batholiths, even when buried under overlying masses, are raised far above the base level of erosion they will eventually be attacked and swept away. The larger batholiths so far as they may be seen to-day are those to which this has happened. Their upper surfaces are no longer there. They contain quite generally only feeble and ill-concentrated mineralizations, although such mineralization may be widespread.

A very brief review of base-leveled mountain systems containing extensive igneous intrusions; such as might have produced ore deposits, confirms this observation. The old mountain ranges of New England and Canada, as well as more modern but extensively eroded batholiths like the Sierra Nevada and the Central Idaho, carry only scattered and generally worthless minerals.

Good ore deposits are not wanting in ancient mountain systems, but they are found in positions where they have been protected from excessive erosion. In another expression, they have remained wholly or in part, *below the base level.* Bisbee is an excellent case in point. It has twice been exposed by erosion, first in pre-Cretaceous times and again in the Quaternary. But in both cases, apparently, the erosion barely reached down to the main deposits, which have been preserved far more thoroughly than most others, so that they remain as good an example of their type as can be found anywhere.

For all local details one may refer to many interesting publications, particularly Ransome's "Geology and Ore Deposits of the Bisbee Quadrangle," U. S. Geological Survey, Professional Paper No. 21 (1904) and the "Geology of the Warren District," by Bonillas, Tenney and Feuchere, Bulletin No. 117, September, 1916, American Institute of Mining Engineers. It is from these papers that I get most of my facts. One or two observations designed to link these facts with others may be suggestive, or at least worth some attention.

The Bisbee batholith so far as exposed (in Sacramento Hill) is a tiny one. How large it may be at some lower horizon is pure guess work; the only certain thing is that it expands going downward in such a way as to suggest that the known portion is only the crest of a roughly conical mass, the base of which may be many times the area of the whole explored district. This little batholith never has been the core of a prominent mountain mass, its scale is merely that of an outlier. That is why it remains so nearly intact. It was formed on the fringe or flank of a Permian mountain chain in which batholithic action, with its accompanying compression of the upper crust, including the sedimentary strata lying upon it, occurred on a grand scale. But Bisbee is plainly not within this chain. The rocks are not violently contorted, but only gently inclined. They show only the beginnings of contact metamorphism. Bisbee lay in the foothills of the Permian mountains. Its topography, as shown by the position of the overlying Cretaceous formation, was typical foothill topography *i.e.*—rocky hills and talus slopes. The big mountain chain lay toward the west or southwest, the lowlands toward the northeast.

The mountains seem to have risen rapidly to a great height, producing immediately the climatic change referred to. This is indicated by the rocks of the Plateau region, which, though elevated are otherwise nearly undisturbed to the present day and have been, of course, at all preceding times back to pre-Cambrian. On this plateau the Moenocopie formation, of Permian or early Triassic age consists of red shales containing only salt water, a typical desert deposit. It represents with practical certainty either an inclosed basin, like the present Great Basin of Nevada and Utah, or a longitudinal valley made arid, like the present northward extension of the Gulf of California, by a barrier that shut on the moisture from the ocean. In later Triassic times this plain was covered by a coniferous forest of large trees, (the famous petrified forests of Arizona are a remnant of it) similar to those growing on the plateau at present; showing a considerable amelioration of the climate. It is probable that this flat country extended much nearer to Bisbee at that time than the present margin of the plateau, but the indications are that it did not reach to it, perhaps not across much of the present intervening mountain belt, because it seems that the Bisbee district was elevated enough to be undergoing moderate erosion. At any rate its rocks had been tilted and had been deeply scored before the Lower Cretaceous times. It is also not improbable that the change of climate in Triassic times was due to the wearing down of the highest crests of the Permian mountains.

Those mountains might be called the Old Mohave mountains, for the base leveled core of them may be seen in Southern California, largely upon the Mohave Desert. This old range must not be confused with any of the present mountains in that region, which are merely fault

blocks of recent age. On those blocks may be found much older rock masses all of which show the characteristics of a first class mountain building effort. They are sharply compressed in folds, liberally intruded by granite, and so thoroughly metamorphosed into marble and schists that there is generally no means of identifying them. One mass, however, in the San Bernardino Mountains is so large that its central portion has escaped the pervading metamorphism and in it I have found abundant Paleozoic fossils, enough to identify these great marble fragments with the limestone formations of Arizona. There are enough similar patches in the intervening region to make it certain that the whole Paleozoic series of southern Arizona extended through uninterruptedly to the Pacific Ocean.

What the limits of the Old Mojave mountains were I have only the dimmest idea. Perhaps in a rude way they are indicated by the Desert Zone described by Ransome. The chain was certainly not less than 100 miles wide, probably 200 miles, and certainly many hundred miles long; undoubtedly a mass greater in every respect than the Sierra Nevada of the present day. Similar patches of crystalline marble are found here and there along the coast as far north as San Francisco, and undoubtedly further, but in the neighborhood of Redding, 180 miles north of San Francisco, the Paleozoic rocks have changed their character. They no longer show intense metamorphism or any evidence of belonging in the core of such a mountain range. If the Old Mohave range went that far north therefore, it was near the coast. Southeastward the range doubtless extended a long distance, far into Mexico, but to what point we must leave to future investigations.

The imposing batholithic action along this great Permian range was accompanied by widespread mineralization, but in the core of the range only the roots of the ore deposits remain. The bulk of them has been removed by erosion. Probably it disappeared largely even in Triassic time.

Although the Bisbee deposits are of Permian age, it is far from safe to assume that the other copper deposits in the region are of the same age. Another great geologic "revolution" occurred at the end of Mesozoic time and it is to this one and to the disturbances and upheavals that continued more or less through Tertiary times, becoming especially pronounced toward the end of the Tertiary, that the continent owes its present form. Again batholithic action occurred on a considerable scale and ore-deposits were formed in the region. The Tombstone mines, barely 20 miles from Bisbee, belong to these later times. Some of the great copper mineralizations such as Ajo, Ray, Cananea and Globe, may also be later, but so far as I know their age is not so definitely fixed.

The exploitation of the Bisbee district will be better understood by retaining the few pages relating to it in the first edition.

Bisbee District (in 1909).—Dr. James Douglas describes the Copper Queen mine in a paper in Vol. XXIX, 1899, *Transactions* of the A. I. M. E. The ore yielded, "about 7 per cent. copper after a rough selection in the stopes where about one-half the total material broken is rejected. To supplement the deficiency in filling the stopes, barren ledge matter from exploratory drifts is used. Though the timbering of worked-out portions of the mine is thus enforced, so violent is the movement of the ground that the timbers are dislocated or crushed to chips. About 30 ft. board measure of timber (from Puget Sound) is buried in the mine to the ton of ore extracted." This is a terrific cost for timber. At an average price of $24 per M. delivered at the mine, we have on this basis 75 cents a ton for timber alone. From 7 to 10 tons of ore are extracted per foot of opening work. A large part of the exploratory openings have to be closely timbered, and the cost for this work is high.

The reason for the conditions described will appear very plainly from a consideration of the structural relations of the orebodies. Dr. Douglas says:

"With regard to ledge matter and the oxidized ore, my own opinion is that they are the product of replacement and local concentration; that where there is ledge matter to-day there was, originally, more or less compact iron pyrites carrying a small percentage of copper; and that during the process of alteration not only did the ferruginous solutions of alumina replace the pyrites, but the copper, by a process of segregation akin to crystallization, was concentrated and collected into areas of limited size, thus constituting the comparatively small bodies of oxidized ores which are disseminated irreguarly through the very large masses of ledge matter. As the outline of the masses of ledge matter has never been traced, it is impossible to determine their actual size, but approximately there has been exposed above the 400-ft. level not less than 10,000,000 tons of edge matter."

Since at the time this was written not much over 1,000,000 tons of ore had been mined above the 400-ft. level, it is probable that Dr. Douglas believes that the ores now occupy approximately one-tenth of their original volume; the remaining nine-tenths being now "ledge matter," mainly ferruginous clay.

Nothing could be clearer than the above description as an explanation of the cost factors. All the altered residual masses must be explored; this means that the mine development, in addition to the shafts and drifts necessary to reach the ore, must search through 10 cu. ft. of difficult mining ground for every cubic foot to be extracted.

At various places in the mines large masses, like kernels, of original pyrites, still exist, surrounded on all sides by the "ledge matter." Although workable ore is found along the periphery of these masses, the pyrite itself is not payable. No concentrating ore has yet been found in the district. All the ore raised from the mines must be smelted, consequently it must be slelected as much as possible.

To sum up—there are in these mines three powerful factors that make for high costs: (1) A very large proportion of development work; (2) soft ground, requiring slow, cautious working and heavy timbering; (3) careful selection imposed by the necessity of smelting the whole product, thus imposing a high subsequent metallurgical cost. This is the most imperative factor of all, for it can be shown that in this case lower icosts at the expense of having to smelt lower grade ores might result in fr ghtful losses of profits. To mine 4 per cent. ore for $3 a ton against 7 per cent. ore at $6 a ton, smelting costs remaining the same, would increase the cost of copper about 0.82 cents a pound, or $16.40 a ton.

During the ten years since the above was written the Copper Queen has produced 900,000,000 pounds of copper and the Calumet and Arizona 600,000,000. The total output of the district at the end of 1918 was

Copper Queen	1,660,000,000 pounds
Calumet & Arizona	771,000,000 pounds
Shattuck-Arizona	109,000,000 pounds
	2,640,000,000 pounds

If we add the production of the present year, besides some shipments not included in these figures, we find a total production of not less than 2,800,000,000 pounds of copper alone. Adding the equivalent in copper of other metals we may count on a metallic output equal to 1,500,000 tons of copper. This comes from a total area not exceeding 2400 acres. I suppose the total output of ore has been about 25,000,000 tons. In round figures therefore, the output has been 10,000 tons of ore and the equivalent of 1,250,000 pounds copper for every acre within the extreme points explored in the district.

This is not all. It is probable that not less than 5,000,000 tons of good ore is fully opened up in the limestone mines, besides more than 20,000,000 tons of disseminated ore in the porphyry of Sacramento Hill. Discovery of new ore is proceeding at the usual rate. There is fair reason to suppose that the ultimate production of this tract will be at least twice the amounts mentioned.

These statements make a curious commentary on the progress of exploration, knowledge, inference and practice in this kind of mining. The late Dr. Douglas, for 35 years the active head of the Phelps-Dodge mining interests, was for many years extremely cautious in his expectations of this district. For a long time he felt that the valuable ore was confined to erratic concentrations which though, rich and profitable while they lasted, might come to an abrupt end. It was for a quarter century the custom of Phelps, Dodge and Co., to retain as surplus in the treasury an amount of cash or securities equal to the total sum invested in their mines. This was a drastic assurance that they would not pay themselves profits that were not really profits. By this plan the business

might come to a sudden end, but the stockholders would be assured of the safety of their entire investment. Dividends paid after making this provision could surely be regarded as income even if the mines should become worthless holes and their equipment rusty junk. Dr. Douglas' belief that the original sulphide mineralization was not pay ore has been proved not to be true. This fact alone must have altered profoundly his early conception of the district. It is probable that in thirty years years the development of the country, plus the advancement in the art of mining, has reduced the minimum grade of merchantable ore from about 5 per cent. copper to near 1 per cent.

PRODUCTION OF COPPER QUEEN FOR THREE YEARS. LIMESTONE MINES ONLY

	Dry tons	Gold, oz.	Silver, oz	Copper, lb.	Lead, lb.
1915	775,000	18,974	943,000	86,000,000	9,388,000
1916	878,000	24,030	1.096,000	99,500,000	9,421,000
1917	790,000	19,156	828,000	93,500,000	6,870,000
	2,443,000	62,160	2,867,000	279.000,000	25,679,000

From this we see that the present, or recent, average of the ore is about 114 pounds copper, 10 pounds lead 1.1 oz. silver and 50 cents gold per ton. The value of all these, expressed in copper alone is about 125 pounds.

Year	Number of employees at mine	Development, feet	Number of employees at reduction works	Tons smelted	Copper smelted
1915	1883	68,431	965	1063,329	125,144,000
1916	2530	80,853	1118	1,304,523	171,894,000
1917	2264	58,518	1485	1,276,817	191,581,000
	6677	207,802	3569	3,644,669	488,619,000

The output of the mines per man per year is 366 tons, the tons per foot of development is nearly 12; but the latter is somewhat above the average. The pounds of copper, including its equivalent in other metals, per man per year, is about 45,700 pounds, and at the smelteries 145,000 pounds; for both mining and smelting about 34,000 pounds, or somewhat less than 100 pounds per day.

Calumet-Arizona.—The Copper Queen mines begin at the surface or outcrop, the Calumet and Arizona has always been a "deep level" mine. The remarks made upon it in the first edition are here retained

Year	Copper, lb.	Price	Value copper	Gold and silver	Total value	Tons
1904	31,638,660	12.562	3,974,448	$195,926	$4,170,374	205,807
1905	31,772,896	14.923	4,741,484	178,843	4,920,327	202,952
1906	37,470,284	17.96	6,729,612	238,464	6,968,076	215,671
1907	30,689,448	18.103	5,554,781	210,846	5,765,627	232,460
1908	28,048,329	12.948	3,631,655	234,358	3,866,013	265,344
Total	159,619,517		24,631,978	$1,058,437	$25,590,317	1,122,234

Year	Development, feet	Dividends	Excess of assets	No. of men mining	Estimated cost of mining per ton
1904	19,955	$1,300,000	$1,823,992	583	$6.15
1905	21,737	1,700,000	....	629	6.68
1906	14,818	2,600,000	....	597	6.00
1907	23,016	3,300,000	....	621	5.70
1908	30,680	800,000	$3,423,269	567	4.60
	100,206	$9,700,000			

Copper equivalent	166,500,000 lb.
Copper equivalent per ton	148 lb.
Approximate earnings	$10,900,000
Approximate cost	$14,790,000
Cost per ton	$13.18
Cost per lb. copper	8.9 cents
Tons per ft., development work	11

The first report that gives actual operating figures to any extent is that for the year 1908. The comparison, with the five-year period is interesting. The amount smelted was 265,344 tons containing the equivalent of 113 lb. per ton, against 148 for the five years.

		Per Ton
Operating mines and smelters	$2,089,158	$7.87
Current construction	195,408	0.74
Salaries and general expense	32,011	0.12
Refining and marketing	368.529	1.39
Ore purchases	22,964	0.08
Total	$2,708,070	$10.20

The cost per pound copper is 9 cents.

There is nothing to indicate the comparative cost of mining and of smelting except the number of men employed in each. The total number at the mines averaged 567, and at the smelter, 484. It seems probable that the total cost of mining will equal $6 a day per man employed, this

being estimated on the theory that the labor cost is 60 per cent. of the total, which would indicate a mining cost, including development and everything, of $4.60 a ton. This cost is good for Bisbee and I believe below the average of this mine. Smelting would cost, on this basis, $3.18 per ton, which seems very good.

Superior and Pittsburgh.—This property is a consolidation of several others which undertook a bold and expensive exploration of a tract of 1388 acres lying in the trend of the assumed extension of the Copper Queen orebodies. The venture has been successful as far as finding ore is concerned, but has not yet become profitable. It is heavily capitalized, the stock issued being 1,500,000 shares at $10 par value. That the outcome is viewed with confidence by the stockholders, or by the public, is proved by the present market value (April, 1909) for the stock of $13 a share.

Operations have been carried on since the consolidation at a loss of $1,031,284 in three years. The output and results have been as follows:

	Dry tons smelted	Feet development	Copper	Gold and silver	Total value
1906	95,779	40,019	9,044,875	$21,941	$1,645,339
1907	111,710	23,332	9,691,905	33,401	1,787,544
1908	214,847	29,572	21,924,259	121,296	1,839,000
	422,336	92,923	40,660,539	$176,638	$6,271,883

The equivalent of copper per ton is 100 lb. The cost per ton averages $17.30, and the cost per pound copper 17.3 cents. Tons per foot development, 4½.

A great improvement over these averages is shown by the report for 1908. The copper equivalent in the ore for that year is 108 lb., nearly equal to Calumet & Arizona for the same year. Here is the record:

		Per Ton
Tons smelted dry	214,847	
Mining and smelting	$2,490,857	$11.60
Current construction	30,938	0.14
Salaries and general	36,648	0.17
Refining and marketing	264,869	1.23
Interest	84,719	0.40
	$2,908,031	$13.54

The cost per pound was 12.54 cents

Later History of the Calumet and Arizona

On the occasion of the visit of the American Institution of Mining Engineers to Arizona in September, 1916, this Company prepared for distribution, a pamphlet describing its history and properties, and I

can do no better than to quote this concise bit of mining history almost in full.

Early History.—Until the fall of 1900, the Copper Queen Consolidated Mining Co. was the only company of any importance in the Warren District. While hopeful prospectors had located many claims south of Sacramento Hill, these claims were generally looked upon as worthless. Even when ore had been developed from the Spray Shaft of the Copper Company to within a short distance of the "Irish Mag" sideline, the old belief that ore would end at Sacramento Hill prevented the development of the "Irish Mag" and of claims further south.

In 1898 Capt. James Hoatson of Calumet, Michigan, visited the Warren District. After becoming familiar with the occurrence of ore in the district, and learning the general location of ore bodies near the Spray Shaft, he became convinced that a large orebody would be found in the Irish Mag claim. He interested friends in Calumet in his idea, with the result that the Lake Superior and Western Development Co. with Charles Briggs as President was formed to develop the Irish Mag and other claims. In March, 1901, the company was reorganized as the Calumet and Arizona Mining Co.

The Irish Mag Shaft was started in November, 1900, and was sunk to the 750-ft. level before any drifting was done. Mr. I. L. Merrill was the first Superintendent. The first work was disappointing, and it became necessary to raise more money before continuing the development. At this time Mr. Thomas F. Cole, of Duluth, Minnesota, became interested in the prospect. He secured money with which to continue the work from Mr. Henry W. Oliver and others of Pittsburgh and Duluth.

A little ore was found on the 850 and 950-ft. levels, and a small smelter was started in Douglas. In the spring of 1902 the Northeast Drift on the 1050 level cut the main Irish Mag orebody. For 325 feet the ore developed by this drift averaged over 9 per cent. copper. From this time the success of the Company was assured. Shipments to the Douglas smelter were commenced in November, 1902, and the first dividend of $400,000 was paid in December, 1903. Early in 1903 the Oliver Shaft was started to develop the Senator group of claims and the following year large orebodies were found on the 1050 level of this mine.

Development Companies.—In 1902 and 1903 the success of the Calumet and Arizona Mining Co. led several of the men who had been responsible for this success to explore other ground lying still further south and east of the productive area. The "Junction Development Co." "Pittsburgh and Duluth Development Co." "Lake Superior and Pittsburgh Development Co." and "Calumet and Pittsburg Development Co." were formed to develop various groups of claims. The officers

and management to these companies were the same as of the Calumet and Arizona Mining Co.

Exploration was carried on under the most discouraging conditions. Shafts had to be sunk 1000 feet or more before there was any likelihood of finding ore. Usually the surface gave no idea of where orebodies might lie, and thousands of feet of development work in barren ground had to be done before orebearing horizons were located. In the Junction Shaft and the Briggs Shaft great flows of water were encountered, which at times stopped all progress for many months, until the ground could be drained. Although the volume of water pumped from the Junction has exceeded 4000 gallons per minute and the Briggs has pumped over 2500 gallons per minute, during 13 years of fighting these heavy flows of water, the pumps have never been lost.

Many million dollars were spent before any of the shafts became self-supporting. Although in one case eight years elapsed before commercial ore was found, great mines were finally developed on all four properties.

In 1906 the four smaller companies were combined to form the Superior and Pittsburg Copper Co., which was absorbed by the Calumet and Arizona Mining Co. in 1910. In 1913 the American Saginaw Development Co. was also absorbed by the Calumet and Arizona Mining Co.

Later History.—In 1910 and 1911 the development of wonderful sulphide orebodies in the Junction and Briggs Mines made these mines the greatest in the enlarged Calumet and Arizona property. The increasing proportion of sulphide to oxide ore caused by these large orebodies in the lower mines was the principal reason for building the new and larger smelter in 1912 and 1913.

In 1913 the Irish Mag Mine, the beginning and cause of the success of the Calumet and Arizona Mining Co., was practically worked out and closed down. The bottom of the limestone was reached on the 1350-ft. level of this mine. The Oliver, Cole, Hoatson, Briggs and Junction Mines are all producing.

The present monthly shipments to the Douglas smelter average about 68,000 dry tons of ore, from which 5,800,000 lbs. of copper are recovered. In addition about 300 tons per day of low grade pyritic fluxing ore is shipped to other smelters.

To prevent depletion of ore reserves by this large production, it is necessary to do an enormous amount of underground prospecting. The extreme irregularity in distribution and shape of orebodies makes the footage of drifting and raising necessary to develop a ton of ore far greater in Bisbee than in any other large copper district. At present the drifting and raising per month carried on by the Calumet and Arizona company alone averages over 9000 feet. In the most productive part of the district, in order to find all the ore it is necessary to do over a mile of development work per acre. This work finds from 60,000 to 80,000 tons of ore per

acre. The great amount of drifting and raising per ton of ore makes it impossible to develop in advance the ten or twenty years' life which is considered necessary in the case of the great low-grade copper mines. Yet the fact that the ore reserves show a constant, though small increase makes it certain that the life of the property will be long.

The Calumet and Arizona Mining Co. now owns about 2005 acres of mining claims in the Warren District. Nearly three quarters of this area is absolutely undeveloped, and only the fifteen acres of the Irish Mag claim are considered to be worked out.

Summary of Production.—In less than 14 years, from the time shipments started from the Irish Mag Shaft to July 1, 1916, the present Calument and Arizona mines produced 5,763,226 dry tons of ore, from which 634,694,594 pounds of copper were recovered. The gold and silver values in this period amounted to $6,913,072. The dividends paid before July 1, 1916, reached a total of $25,726,661.75.

The last paragraph is particularly enlightening. It may be noted that the dividends were up to this time almost exactly 4 cents per pound of copper. It will be noted also that the gold and silver recovered were worth about 1.1 cents per pound. At the summer of 1916 copper had averaged nearly 16 cents a pound during the life of this mine; adding the gold and silver it must have been about 17 cents. The operating costs, plant charges, investments and working capital must have absorbed about 13 cents a pound.

It will be noted that the ore from this mine is not as high-grade as that of its neighbor. In 1916 it produced 85 pounds copper per ton of smelting ore; in 1918 about 86 pounds. In the latter year the average number of employees was 1636 at the mine alone. Their production was 50,909,000 pounds, 31,000 pounds per man per year.

The Calumet and Arizona smeltery at Douglas is said to be one of the best in Arizona, particularly in the way of labor saving devices. In 1918 the yield in copper per man for the year was about 120,000 pounds; in tons about 1200. In mining and smelting combined the output per man per year was some 26,000 to 27,000 pounds. In 1918 the efficiency was low and the costs high; but in the main the lower output per man as compared with the Copper Queen is explained by the lower grade of the ore, the greater depth and wetness of the mines and the larger proportion of development work, both per ton and per pound—in other words the mines are not so good.

Neither company publishes any cost details, although both give financial statements and many facts of interest. One may state sweepingly that during the past ten years no new element of importance has been introduced to alter the operating practices or costs. The latter change from time to time according to the proportion of development work, the state of the labor supply, the price of wages and materials,

and, more particularly, to the grade of the ore. We have seen that the yield of metal in mining and smelting per man per year has lately been, for the Copper Queen some 45,000 pounds, for the Calumet and Arizona about 31,000 pounds. In 1915 these outputs would have meant a cost for copper of about 5 and 7 cents respectively; in 1919 they meant about 9 and 12 cents respectively. These costs are not complete. To them must be added freight on ore from mines to smelteries, freight on copper to New York, refining, general administrative and selling expenses, taxes and depreciation. The lowest cost per ton for mining ever attained by the Copper Queen was, I believe about $5.00, by the Calumet and Arizona about $4.50, in both cases in the period between 1912 and 1915. At present it must be 60 to 80 per cent. higher.

I have recited at various places in these pages about all the facts in regard to the costs of operating these mines that seem to have any general interest; but some facts on power, smelting, etc., may be added for reference.

Most of the power, at least in the southern part of the State, is made from the fuel oil. At the best plants a barrel of California oil 18° Beaumé, weighing 328 pounds, makes from 300 to 315 kilowatt hours of power. In such a plant, for instance that of Ajo, the power is made in Curtis steam turbines, driving generators of 7500 K.W.H. The steam pressure used is about 250 pounds with 100 to 110 degrees superheat. I suppose such a plant is about as efficient as can be had at a mining plant.

It will be noticed that each pound of oil makes from 0.9 to 0.95 K.W.H. Before the war a pound of such fuel in some places would cost only a little over a half cent (oil at $1.70 a barrel). The fuel cost per K.W.H. was therefore under six mills per K.W.H. and the total cost was said to be as low as 8 mills. Of course the power-cost items belong to the pre-war period and at present are at least 60 or 70 per cent. higher.

From these figures the cost rises at various places very considerably. At the Copper Queen Plant at Bisbee, at the end of 1916 the fuel required was about 3 lbs. of oil per K.W.H. and at various other places more than that. Such a consumption of fuel would indicate a cost of more than 2 cents per K.W.H.

The progress of the industry has called attention to the possibility of reducing these costs by means of electrical transmission. Some water power is made by the Government at Roosevelt Dam and delivered at the Inspiration mine at Globe. I suppose that under present conditions this power must be the cheapest used in the state. A considerable amount might be obtained from the Colorado River, but the transmission lines of some of the mines would be very long and such a project depends on Government co-operation, which means usually prolonged and dilatory negotations. But there is a standing argument in favor of manufacturing the electrical power at the coal mines, or rather in a coal

field, in the northeastern part of the state in the Plateau region, from which transmission lines might reach practically all of the mines at distances from 100 to 200 miles. The price of oil seems likely to grow higher as time goes on and coal used at the various districts has to be transported by rail distances of several hundred miles. The cost of such transportation is usually several times the cost of mining the coal on the ground. I suppose that under ordinary conditions a large power plant placed immediately at a coal mine would produce power for 3 to 4 mills per K.W.H., say about $35 per horse power per year. What the transmission lines would cost I do not know, but it seems as if the large amount of power used by the mines, plus a considerable amount used in agriculture and other industries in the state makes some such development more or less inevitable.

Smelting at Douglas

At the end of 1916 the Copper Queen smeltery, with a capacity of 100,000 tons a month, cost about $4,000,000. The Calumet and Arizona smeltery at the same place with the addition of a sulphuric acid plant, cost nearly the same amount. The average copper content of the ore at the Copper Queen was 7½ per cent. and that at the Calumet and Arizona about 4½ per cent. In the former case the high grade was explained by the fact that a considerable quantity of high-grade concentrates and also a good deal of high-grade crude ore was brought from other mines. The converter matte in this smelter ran about 38 per cent. The coke used in the blast furnaces was about 12½ per cent. of the charge. The per cent. of ore in the charge was about 75 per cent. The tons smelted per square foot of hearth per day was about 5.8 per cent.; about 3 per cent. limestone was used for flux; 295 cubic feet of air at an average pressure of 28 ounces was used per square foot of hearth area. The copper in the slag was 0.38 per cent. In the reverberatory in which the fine ore is treated the matte fall was 26 per cent.; the copper in the matte 34 per cent.; the copper in the slag 0.35 per cent.; 0.8 per cent. barrel of oil was used per ton of charge and 4¾ pounds of steam per pound of oil, obtained from the waste heat. Of recent years, experiments in these reverberatories in the way of increasing the burning capacity by enlarging the drafts for escaping gases has increased the capacity from 400 tons to 800 tons per day. These reverberatories at the Copper Queen mines have an area, I believe, of 19 feet by 91 feet. Those at the Calumet and Arizona are somewhat larger.

At the Copper Queen plant the amount of ore treated per man per day was about 3 tons. At the Calumet and Arizona where labor saving devices were more extensively used, but where on the other hand, the amount of sampling required for custom ore was very much less, the tons stated per man was about 4½.

These are the main elements as far as I know in the cost of operating, and in detail that cost will be determined by the price of labor in the various mines.

Growth of Phelps-Dodge and Calumet and Arizona Companies

One who studies the economics of mining should not fail to take note of the progress of financial and industrial organization as shown by the chief corporations. It must strike anybody that the problem of reducing costs is confined principally to three elements: (1) to secure cheaper power, (2) to substitute power for labor, and (3) to prevent useless duplication of effort. To accomplish these purposes is the chief function of capital. To illustrate this process it seems worth while to retain in somewhat condensed form the following pages from the first edition which were taken largely from the prospectus of Phelps-Dodge and Company, issued in 1909.

Statement by Comptroller

Copper Queen Consolidated Mining Company

"This property consists of one hundred and thirty-five (135) mining claims in the Warren mining district, Cochise County, near the town of Bisbee, Arizona, a large smelting plant at Douglas, of a capacity of 3000 tons a day, which treats the product of the mines of the Copper Queen Company, and for the time being the ores of the Moctezuma Copper Company, and does general custom work.

The company conducts a mercantile business, and has large stores and warehouses in Bisbee and Douglas, and a branch store in Naco, Arizona, as well as other pieces of real estate. It also owns mining interests in other localities.

"For five years past the production of the mines has been 294,595,687 pounds.

"The output of the Douglas Reduction Works, including purchased and custom ores, for five years past has been 363,121,911 lbs.

"The earnings of the company during the five years have been $22,868,778.24.

"The difference between earnings and dividends is represented by expenditure on increased plant facilities, and undistributed assets, consisting of the larger stock of coke and fuel necessitated by increased operations; and the accumulated stock of ores at the works, amounting in value to over $1,000,000, as well as by increased cash and increased reserves.

"A large portion of the company's mining property has as yet been undeveloped, though situated within the recognized mineral zone of the district, and owing to the difficulty of holding up the soft, shifting ground in which the ore occurs, it has always been found impossible to block out ore reserves as large as mines of such capacity elsewhere have usually maintained, as nominally in sight. There is, however, at the present time as much ore in sight as at any other period of the mine's history.

"The valuation of the company's property as of November 1, 1908, exclusive of the mines, is as follows:

Invested in plant	$4,974,866.77
Other assets	10,915,492.97
Liabilities	1,275,573.40

Moctezuma Copper Company

"This property consists of about 2500 acres of mineral ground in the State of Sonora, Mexico, on which has been opened the Pilares mine. This is on a mineralized body, oval in shape, and which retains approximately its dimensions between surface and the seven hundred foot level. It is about 1700 ft. in diameter from north to south, and 1200 ft. in diameter from east to west, and contains a large area of profitable ore. A narrow gage steam railroad five miles in length connects the mine through the Pilares Tunnel with the concentrating mill at the town of Nacozari. The tunnel itself, with its branches, is over a mile in length, and is large enough to allow of the railroad cars reaching through it the different sections of the mines, and receiving their charge from large bins excavated out of the ore. These bins are of a capacity of several thousand tons each, and are fed through chutes extending to the surface levels, the chutes also being excavated from the mineralized ground.

"The quantity of what may be considered ore depends entirely upon the grade which it is profitable at a given price for copper to work, but the mine is at present opened up for an extraction of 1500 to 2000 tons a day of ore of an average grade of three per cent. The daily capacity of the concentrating mill just completed at Nacozari is 2000 tons. At Nacozari is a well-designed power plant, equipped with Curtis turbines of over 4000 horse-power, for transmitting high voltage current to both the mill and the mine. For the time being it is found to be more profitable to convey the concentrates and rich ores by the Nacozari Railroad to Douglas, Arizona, seventy miles distant, than to smelt them on the spot, the ores being treated at Douglas at the same profit to the Copper Queen Company as though they were custom ores supplied by an unallied customer. This feature of the company's operations explains the comparatively small quantity of supplies carried by the Moctezuma Copper Company as compared with the other companies.

"The old concentrating mill, which is still intact, with its very efficient gas engine and gas-generating plant, which up to within a few months treated 600 tons of ore a day, is now out of commission, though it can be started at short notice as a supplemental plant to the new mill, should this course be desirable.

"The production for the five years past has been 53,858,751 pounds.

"The increased capacity of both the mine and the concentrating mill, owing to recent improvements, is indicated by the fact that in May, 1908, the production was 784,892 lb. of metallic copper, whereas by the month of October it had reached 2,300,000 lb. of copper, contained in 9500 tons of 12½ per cent. concentrates. A production of approximately two million pounds of copper a month can now be maintained; and, if the market demanded it, this production could be increased to three million pounds per month.

"The net earnings for the five years while the mine was still in a stage of development and the works were contracted, were $3,617,295.

"The company has built and owns the whole town of Nacozari, and has provided it with a well-furnished library and amusement hall, a thoroughly equipped hospital, hotel, boarding houses, and schools. At the Pilares mine the company has provided its workmen with comfortable houses and supports a school. At both Nacozari and Pilares the company has large stores and warehouses, and conducts a profitable mercantile business.

Invested in plant	$3,046,384.32
Other assets	944,663.08
Liabilities	347,221.22

THE DETROIT COPPER MINING COMPANY OF ARIZONA

"The mines of this company are situated in the Clifton district, Arizona, in the same beds of felspathic rock which at the present time are yielding the product of the Arizona Copper Company, the Shannon Copper Company, and certain less prominent organizations. The property owned by the company consists of one hundred and forty-five (145) mining claims, and the ore now extracted amounts to about 36,000 tons per month, yielding about three per cent. of copper. The bulk of the ore is concentrated mechanically to a grade of about fifteen per cent., and smelted at Morenci in the company's own smelting works.

"The company's production for the five years has been 86,247,889 pounds.

"The production for the eleven months of the present year has increased to 21,500,000, owing in great measure to improved facilities for treatment. The future production with the present equipment can be maintained at approximately two million pounds of copper per month.

"The earnings during the past five years have been $3,467,810.81.

"The company runs a large store and hotel, and owns considerable other property in the town of Morenci, besides a powerful pumping plant on the San Francisco River seven miles distant.

"The valuation of the company's property as of November 1,1908, exclusive of the mines, is as follows:

Other assets	$2,150,101.00
Other assets	2,934,465.97
Liabilities	149,878.48

"The ores from the Copper Queen mines carry about twice the quantity of copper contained in those of the Nacozari and Morenci districts, but this advantage is offset by the higher cost of mining the Queen ore, owing to the character of the deposits in which they occur. Moreover, as the Queen ores cannot be subjected to preliminary mechanical concentration, which raises the smelting grade of the Nacozari and Morenci ores, they must be subjected to furnace treatment as they come from the mines; hence the cost for smelting a ton of Queen ore is higher than the cost calculated on a tonof crude Nacozari or Morenci ore."

Year	Output, pounds	Operating profits, dollars	Profits per pound, cents	Average price, cents	Cost, cents
1903	37,257,470	2,201,640	5.9	12.6	6.7
1904	50,151,552	2,960,659	5.9	12.562	6.962
1905	64,625,955	5,609,486	8.7	14.923	6.223
1906	79.219,655	7,625,854	9.63	17.96	8.33
1907	63,341,055	4,471,137	7.0	18.103	11.103
Five years	294,595,687	22,868,778	7.76	15.7	8

The amount invested in plant is given at $4,974,866. Since it is stated above with reference to the Bisbee district, by Dr. Douglas that the ores of the Copper Queen average about 140 lb. copper per ton, an approximation that is borne out by the record of the neighboring Calumet & Arizona mine, it does not seem rash to say that the mining plant is equal to a capacity of 600,000 tons a year, and the smelting plant to 900,000 tons a year. Averaging the two we might say the plant is such that an output of at least 750,000 tons a year can be taken care of. The cost of mining and smelting plants may, therefore, be approximated at $7 per ton of annual capacity. Taking into consideration the character of the orebodies exhibited by the remarks in the prospectus, it seems fair to calculate the amortization of plant in a period not exceeding fifteen years from the beginning of the term in question. This requires an annual instalment of 10 per cent. To this should be added depreciation at 6 per cent. to cover the current construction. Applying these figures, not the whole period, but to the maximum capacity reached at the end, we get

For amortization	$0.70 per ton
For depreciation	0 42 per ton
Total	$1.12 per ton

Dividing this by 140 lb., the average amount of copper realized per ton, we get 0.8 cents per pound as the amount that should be added to operating charges for plant account. I am disposed to regard this as a minimum figure and prefer to believe that at least 1 cent. per pound should be added for these charges. This would mean only $2,940,000 in five years for the use of capital already invested and for current construction. It is to be presumed that the company made some profit on treating custom ores, but as these ores must have come largely from other mines owned by the same group, it is not likely that such profits would be sufficient to alter the calculation materially. My estimate of costs, then, for the Copper Queen is as follows;

Average operating cost	8 cents
Average capital cost	1 cent
Total	9 cents

It will be noted that the average is exceedingly close to that figured for Calumet & Arizona: and, further, that a considerable rise was incident to the boom period of 1906–07.

Moctezuma Copper Company

The figures on this property are very interesting in view of the light they throw on the probable results to be obtained from the Miami, Ray, and other new properties of approximately the same grade and type.

Year	Output, pounds	Operating profits	Profits per pound	Average price	Operating cost
1903	10,281,970	456,524	4.44	12.6	8.16
1904	11,061,641	598,992	5.44	12.562	7.178
1905	10,160,016	533,117	5.25	14.923	9.773
1906	12,714,716	1,195,424	9.4	17.96	8.56
1907	9,640,390	833,236	9.64	18.1	9.46
Five years	53,858,751	3,617,295	6.7	15.3	8.6

In this case the plant investment is $3,046,384, and the producing capacity is now easily 24,000,000 lb. a year. Calculating depreciation at 6 per cent. we get an annual charge of $182,800 a year, equal to 0.76 cents per pound. Add this to 8.6 and we have 9.36 cents as the dividend cost. It is very probable that with the increased tonnage now possible, the cost will average not over 9 cents.

On a life of twenty years, the plant may be amortized at 8 per cent., equal to about 1 cent per pound. The selling cost may then be put at between 10 and 10½ cents, a figure that fully bears out the conclusions arrived at from other sources.[1]

Detroit Copper Company

Neglecting the explanation of details, it appears that this company earned $3,467,810 from 86,247,889 lb. copper, equal to 4 cents a pound. The cost must have been about 11.3 cents. The capital invested is only $2,158,106, on which depreciation at 6 per cent. gives an additional cost of 0.7 cents per pound. The dividend cost may be calculated at 12 cents.

In all of the above calculations I have failed to exhibit the copper equivalent for gold and silver contained, because the amounts are not given. In most of these mines, however, the value of precious metals is only 2 to 3 per cent. of the total, so that the figures given cannot be far astray from this cause.

The progress during the last ten years is quickly indicated by the following table, showing the production of the different properties in the year 1916, which is selected because it was a year when the operations were unhampered by external interferences.

Copper Queen Mining Co.	102,685,722 pounds copper
Detroit Copper Co.	17,539,858 pounds copper
Moctezuma Copper Co.	37,789,310 pounds copper
Burro Mount Copper Co.	8,587,398 pounds copper
Bunker Hills Mining Co.	59,299 tons of ore
Stag Canyon Fuel Co.	1,439,904 tons of coal

[1] See Chapter XIII, for discussion of the cost of producing copper from ores of approximately this grade and type.

The output of the Copper Queen smeltery for that year was 171,893,-880 pounds of copper from 1,304,523 tons of ore and the total amount produced from the various mines owned by the company, 153,263,729 pounds.

The Calumet and Arizona shows a similar growth, part of which is already indicated, but that company has also undertaken outside mining enterprises, the principal one of which consists of 75 per cent. of the stock of the New Cornelia Copper Co., which is now capable of producing at least 50,000,00 pounds of copper a year, and has acquired practically all the ore in the Ajo District, the sum total of which must be about 70,000,000 tons.

It is very noticeable in studying the details of mine operations that the progress of such consolidations has made those details less available than they were ten years ago. The Phelps-Dodge Corporation gives its financial results as a lump figure covering all these mines, and the same thing is true of the Anaconda Copper Co. Even the Calumet and Arizona reports are becoming less intelligible from the same reason. I cite these facts not as any criticism of the management of any of these companies, but merely as a indication of the trend of affairs in the American mining business. I have long been convinced that organization on such lines will inevitably continue so long as there is any economy in it.

Costs and Operating Details of Phelps-Dodge Properties.—An examination of the reports of this corporation reveals that many interesting details were published up to the end of 1914 that have not been published since. Although it is my object in this edition to avoid including too many tables of figures it seems desirable to insert some of these statistics for future reference, for the reports containing this information are not now readily to be had.

Copper Queen Mine

	Tons	Copper	Price copper, cents	Dividends	Surplus
1909	595,624	84,429,791	*13	$4,025,000	$10,142,620
1910	596,193	76,428,908	12.826	6,300,000	
1911	619,132	74,489,728	12.36	5,200,000	
1912	786,368	88,280,908	15.51	5,707,351	
1913	867,481	97,181,725	15.37	5,700,000	
1914	732,829	86,066,143	13.57	4,500,000	9,406,691
6 years	4,197,627	506,877,203	13.77	31,432,351	$735,929

* Approximate.

Apparent earnings, after paying for depreciation and all plant extensions $30,696,422, equal to a trifle over 6 cents per pound copper. The average price for the period was approximately 13.8 cents, to which should

be added about 1 cent for other metals making the total receipts 14.8 cents. The grand total cost therefore seems to be about 8.75 cents per pound. The total expenditures were about $44,000,000 equal to $10.50 per ton shipped from the mines.

Analysing these costs we find that the sum credited to depreciation for the period is $3,911,000 for five years. It was not reported in 1909. Probably the total should be $4,500,000, equal to about $1.07 per ton shipped and 0.9 cents per pound copper.

The remaining costs therefore are about $9.43.

The cost of freight to New York, refining and marketing must have been about $6,000,000, equal to 1.3 cents per pound, and $1.57 per ton shipped.

There remains for mining, transportation to smeltery, reduction and converting $8.86. Converting probably cost about 0.4 cent per pound, or 50 cents a ton, bringing down the total to be accounted for to $8.36 per ton.

The cost of reduction is not given but it probably was not far from $2.00 per ton, this being $1.25 for labor, power, supplies, etc., and 75 cents for coke and fuel. The average cost for mining then would be about $6.35 per ton.

There is evidence to support the belief that this cost was divided about as follows:

Stoping ore	$2.30
Exploration, Development, etc	2.00
Tramming, Hoisting and Loading	0.90
Taxes and General	0.90
Freight to Douglas	0.25
Total	$6.35

In 1913 the report of Mr. Gerald Sherman, Superintendent of the mines, contains the following; "Exploration was very active—the footage having reached 105,937 feet." "Four methods of stoping are practiced, the choice depending on local conditions." The comparative costs are;

	Tonnage	Labor	Timber	Explosives	Total per ton
In square setting	612,299	$1.555	$0.473	$0.085	$2.113
In top slicing	20,682	1.010	0.210	0.080	1.30
In cut and fill	58,239	1.170	0.110	0.120	1.40
In shrinkage	3,822				
	694,942	$1.506	$0.434	$0.088	$2.028

It will be noticed that in this year only about 8½ tons were shipped per foot of development work.

CHAPTER XVI

THE PORPHYRY COPPERS

DISSEMINATED SULPHIDE ORES—ORIGIN OF THEIR EXPLORATION—THESE DEPOSITS ARE PREPONDERANTLY AMERICAN—GEOLOGIC ORIGIN—SURFACE LEACHING AND SECONDARY ENRICHMENT—PRIMARY DEPOSITION NOT SUPERFICIAL—CARBONATES—MIXED CARBONATES AND SULPHIDES—ECONOMIC DEVELOPMENTS IN RECENT YEARS—POWER—CONCENTRATED CRUSHING—OIL FLOTATION—COPPER IN SIGHT—MIAMI—CHINO, A STEAM SHOVEL MINE IN NEW MEXICO—RAY CONSOLIDATED—MOCTEZUMA—CLIFTON—MORENCI—ARIZONA COPPER CO.—DETROIT—NEVADA CONSOLIDATED—UTAH COPPER—INSPIRATION.

Porphyry Coppers.—The general supposition that this form of copper mining is a new one requires some qualification. There is no fundamental difference between the western porphyries that have recently excited general attention and the Lake Superior copper deposits which began to be worked about 1846. I refer to the operating conditions and not to geological appearance of the deposits; this fact was referred to in the first edition of this work.

However, it is the development of the disseminated copper deposits of the Cordilleran region on the western border of North and South America that has introduced a controlling element in the copper business of the world. The first beginnings of these western porphyries is more or less obscure because it is difficult to say just when and where the first distinction was made between the ordinary fissure vein deposits that had been generally sought and these particular disseminated ores. It is probable, however, that the first mining of such ores on any considerable scale, was done in the Clifton-Morenci district in Arizona, and that a considerable amount had there been mined and concentrated before the year 1900. It is also not unlikely that similar deposits were worked in other places by more or less the same methods.

But the beginning of extensive developments and of wide-spread interests in these mines occurred about 1903, when Mr. D. C. Jackling succeeded in calling the attention of C. M. McNeil and Spencer Penrose, who were at that time operating chlorination mills at Colorado Springs, to the problem of concentrating and mining the extensive disseminated deposits at Bingham, Utah. Certain experiments indicated the probability that ores running 2 per cent. in copper might be worked at a profit. The result was the formation of the Utah Copper Company and the initiation of the project to mill these ores on a scale which took people's breath away, for it was decided to put in a mill to treat 6000 tons a day and

even 12,000 tons a day was talked of. About the same time Messrs. F. W. Bradley, J. H. McKenzie and Mark Requa had their attention called to similar disseminated deposits at Ely, Nevada and exploration was done in this district in 1904.

It is not my purpose to trace in detail the history of these enterprises but merely to point out the principal facts in the development of the copper business and their relation to the question of costs, profits and future production. In this connection it is well to bear in mind that the peculiarity of the disseminated deposits as compared with the older mines of copper in the west, was the immediate requirement of large sums of money for the necessary construction of plants and development of the properties before production could begin. A necessary factor in success was a large scale of operations. Undoubtedly the projectors of the first porphyry mines felt somewhat appalled at the risks they were taking in asking for the amount of capital required to launch these enterprises.

At this time a mill that would concentrate 1000 tons a day was considered a pretty large one, but such a mill applied to the low-grade disseminated ores that were being figured on would scarcely make any profits at all.

There was for a number of years a great deal of more or less theoretical calculation as well as practical experiment carried on regarding the best means of making these mines pay. While these speculations were going on it was found that the deposits could be explored rapidly and cheaply by means of churn drills or diamond drills, and while plans for milling plants were being matured the amounts of ore indicated as available frequently increased so much that a mill of 5,000 or 10,000 tons a day seemed justified, but it cost a good deal of money to build such plants, vastly more money than any of the projectors were able to furnish. The result was that they had to resort to bankers and to large financial interests. The method of securing funds was to sell securities to the public. In order to make these securities go it was necessary to do a good deal of more or less dignified advertising in which calculations of the amount of copper in the ores and in the deposits, the amounts to be recovered and the expected profits were pretty thoroughly explained. The result was that a wide-spread interest was aroused not only among mining people but among investors in general in the new mining projects; but as a matter of fact, for a period of at least 10 years it was found that the amounts of capital required to bring the properties up to a scale of operations which would create the greatest present value were persistently underestimated and the public was appealed to again and again for additional subscriptions in stocks and bonds. It is probable that no incident in the development of the American mineral industry has been so enlightening to the general public in regard to the nature of the mining business. It seems

worth while to trace the investment of capital and the operating results of this great group of properties through to the present time when it may be said that all of them are thoroughly established.

It is a remarkable thing that so far as known these disseminated deposits are not only entirely American but are confined to the Pacific sea board and belong to the Andean or Rocky Mountain uplifts. It is hard to see any geological reason why similar deposits should not be found in other parts of the world and perhaps they will be. If so, the supply of copper for the next few generations will no doubt be easily obtained, but, judging from the fact that this type of copper mine has been well known for at least 10 years, it may be supposed that it has been looked for in other parts of the world. The fact that none has been reported indicates at least that they are not so common in the eastern hemisphere as in the western; still there probably are enormous areas in Asia and Africa that have not been explored.

The American deposits are easily described for they were in all cases produced by the same geological agency; namely, the irruption of volcanic or plutonic masses through the earth's crust. These masses are described by the general term of batholith, or deep-rock, because they have welled up from unknown depths. They also have the peculiarity of occurring in periods of general continental re-adjustment such as occurred at the end of the Algonkian and also at the end of the Paleozoic and Mesozoic times. It is not, I believe, clear in all cases, to which period of time all of the porphyry deposits belong, there being in some cases no near-by rocks of identifying age; but it is probable, from all I can gather, that all of the American deposits are, geologically speaking, comparatively recent, none being known to be older than those of Bisbee, Arizona, which may be referred rather confidently to the Permian or perhaps to the beginning of Triassic times. The great batholith of Butte, Montana, is known to belong to the end of the upper Cretaceous and perhaps might be classed as Eocene. It seems probable that nearly all of the porphyry deposits belong to one or the other of these two epochs of batholithic activity.

Some of these batholiths are of enormous size; the one at Butte, Montana, has an area of approximately 2000 square miles but this is only a moderate sized one. Other great ones scattered along the Cordilleran system are the great Coast range batholith of British Columbia which seems to have roughly an area of 45,000 square miles, equal approximately to the area of the State of New York. There is a great one in central Idaho with an area of perhaps 20,000 square miles; still another along the Cascade range in Washington and southern British Columbia; and the great Sierra Nevada batholith, the area of which I have not measured. I give these figures to show the immense power involved in the line of action we are considering. Apparently it amounts to nothing other than

a fusion of considerable portions of the earth's crust. Whether this fusion actually reached the surface in many cases or whether it only came near the surface and solidified so that the great batholithic masses have been exposed by the erosion of the remaining crust, is apparently not always clear. Undoubtedly these fused masses, whether they appeared at the surface in bulk or not, were invariably accompanied by volcanic activity of the usual kind.

The batholiths to which the principal copper deposits of the Southwest belong are generally small, mere pygmies compared with the huge ones just mentioned. They frequently have a total exposed area of only a few hundred or a few thousand acres. From this it appears that the amount of economic mineralization has little or nothing to do with the size of the intrusions.

The accepted theory of the mineralizations is that they were produced by waters or gases driven off from the molten masses in the process of cooling and solidification. These gases under enormous heat and pressure are believed, or known, to have the power of carrying metals in solution. With declining heat and pressure these waters or gases are no longer able to carry the metals and the latter are deposited. This usually takes place when the gases escape into the enclosing rocks or into such portions of the batholiths as have been already solidified at the surface or near the surface. This appears to be a simple and comprehensive statement not only of the porphyry coppers but of practically all sulphide mineralizations regardless of their form. In fact the form in which the ore bodies occur apparently has little to do with their origin, but is determined probably by mechanical factors. Thus if the batholith during its process of cooling has been affected by faulting or fissuring, the escaping solutions will probably follow the partial openings thus made and minerals will be deposited in the form of fissure veins. It may be said in passing that such mineralization never occurs in a single isolated fissure. This might be expected from the nature of a fracture in a huge mass of more or less homogeneous rock. The fracturing invariably affects a considerable area in which there are innumerable interconnected and radiating fissures. In fact, if we look at it broadly the earth's crust cannot be accurately described as solid rock. It is more like a rubble in which the fragments may be very large but nevertheless they are mere fragments held together by their own great weight and the pressure of surrounding rocks. When a spring of magmatic waters is in operation, penetrating the earth's crust thus fissured from below, it naturally finds some channels more readily accessible than others. Then of course the mineralization is irregularly distributed. A mineral district is usually an area that has been affected in this manner, usually from a single ultimate source of mineralization, although at the surface and from a miner's standpoint there may be a number of isolated areas; but in

strongly mineralized districts such as Butte, Montana, it is no exaggeration to say that every ore deposit in the district is connected with every other ore deposit in the district along channels or along fissures that are more or less mineralized, although not always mineralized enough to make an ore. In such cases it appears to be a geological impossibility to make a clear distinction between one vein and another vein.

It also happens that, apparently, the process of mineralization may be intermittent; depending perhaps on the forces that produce the fissuring. We may imagine that one set of fissures tap the escaping waters from a portion of the magma and these waters flow for a considerable length of time and produce mineral deposits but that the process becomes quiescent until another rupture in the rocks re-opens the source of a renewed flow. To refer to Butte again, this action appears to have been repeated 3 times at least.

The porphyry coppers are so patently a phase of the same action that I suppose we may say that in every case the disseminated ore bodies have with them some development of fissure veins more or less pronounced. In many districts the mineralizing batholiths penetrate up to sedimentary rocks such as limestones which are frequently extraordinarily favorable receptacles for the minerals carried from the magma by the escaping water. In such cases the ore deposits formed are not disseminated but are frequently masses of almost pure sulphides in which the predominant metal is usually iron, but in which there are frequently commercial quantities of copper as well as almost every other kind of useful metal in varying amounts, but in amounts almost always very subsidiary to the iron. Manganese also occurs in large quantities, sometimes comparable to the iron and sulphur.

The true porphyry deposits are ores which have been produced by solutions permeating great volumes of rock rather uniformly. I suppose there is almost invariably, perhaps quite invariably, a deposition among the more or less minute fractures that occur in all rocks, but in many cases the ore is disseminated in minute particles which seem to have been substituted for some of the minerals in the original rock by being brought there by magmatic waters as they flowed through the fissures or soaked through the rock masses under pressure.

The disseminated deposits thus formed occur usually at the periphery of the intruding batholith; sometimes in the enclosing rocks as in the case at Miami, Arizona, sometimes in the outer crust of the batholith as at Ajo, and sometimes in both. I think it is rare that the disseminated mineralization is found in the solid core of the batholith, in fact I have never heard of a case.

Just what the chemical causes for the dissemination of the minerals in this manner were is probably obscure, but at any rate it has happened on an enormous scale; in many districts areas of several hundred acres many hundred feet thick have been thus affected and copper has been

introduced in amounts varying from 0.2 or 0.3 per cent. up to 2 or 3 per cent. of the rock masses. When the amount of copper is substantially above 1 per cent. such a mass becomes a commercial ore body, providing it contains a minimum, say, of 5,000,000 tons, and thus becomes what is popularly known as a "porphyry" mine or deposit.

During the past 10 years a good deal has been found out about these deposits that was not fully realized during the earlier stages of this industry. At one time it was generally supposed that this kind of mineralzation was superficial. It now appears that there is no good reason for so regarding it. In the first place it is exceedingly probable that all such mineralizations took place at a considerable depth below the surface and that they are now exposed merely by the erosion of the rocks which were once overlying. The depth at which the deposition took place is not known so far as I can make out and it probably varied greatly in different places but the general supposition among geologists is that it occurred at a considerable depth, say 2,000 or 3,000 feet. Now such depth from a miner's standpoint is not superficial; thus we may almost conclude that none of the porphyry deposits are superficial. At any rate some of them have been traced down to depths as deep as 2,000 feet below the present surface. At such depths the difficulty of exploring is of course enormously increased and since the amount of ores known near the surface is at present large enough to cover all immediate mining requirements no particular effort has been made to trace them deeper, but it is probably a fair statement that at present no limit is known to the depth at which disseminated ores of this type may be expected.

To make a reference to the Lake Superior deposits which are from a prctical standpoint disseminated ores, there remains a question whether their origin is the same as the ores under discussion. My own conjecture is that the ultimate origin is the same but that they have been affected by some geological factor, the nature of which is not understood. If they are produced by some variation of the same causes they are an example of such deposits reaching the greatest depths known in the mining industry, for some of the Lake Superior mines are approaching 6,000 feet in vertical depth; and that is not all, because the present surface has been exposed to immense erosion since the deposition of the ores and I would take it to be a conservative estimate that these present commercial ore-bodies were deposited at, at least, twice the depths mentioned.

To return to the western porphyries we may make a sweeping assertion that all the copper was deposited originally in the form of sulphides accompanying a large but varying amount of silica; but upon this original deposition two other actions have been superimposed. Copper sulphides are soluble and as a deposit emerged into the atmosphere by the slow process of erosion the atmospheric waters penetrating into these masses dissolved the first copper reached and carried some of it, or all

of it, to a lower level where it was re-deposited in the form of the rich sulphide, chalcocite. This action would take place, and has taken place, in a vertical zone of 200 or 300 feet in depth in which, by the cumulative action of such a process maintained for an immense period of time the amount of copper might have been increased to 5 or 6 times the original amount. This seems to have been the case in the great deposits of Miami, Arizona where the original sulphides apparently carried about 0.5 per cent. copper but the portion thus enriched which constitute practically the sum total of the commercial ore bodies, have been enriched to as much as 3 or 4 per cent. in copper, the grand average being perhaps 1.5 to 2 per cent.

This is the well known zone of secondary enrichment, a conspicuous feature of practically all the sulphide mines, either of copper or anything else, but particularly of copper. It has always been the object of a vast amount of discussion and investigation. What its chemical causes are, the exact processes by which it has been effected and even is precise limits are all, I believe, matters of considerable uncertainty. At the time the first edition of this book appeared it was generally accepted that the valuable porphyry deposits were produced entirely by this action by the enrichment of an original mineralization too meager to pay. This idea of course put a limitation upon the expectations both of the amount of ore to be looked for and its occurrence at any considerable depth. There was naturally a justifiable hesitation in basing important investments of money on anything less than proved occurrences of ore, but explorations made during recent years have completely demolished the idea that secondary enrichment is necessary for a commercial occurrence of porphyry ore. Many of the most important deposits have not been enriched at all, for instance the great ones at Ajo, Arizona, those at Nacozari, Mexico, at the Braden mines in Chile and also at Chuquicamata in Chile. It is indeed common that ores or ore bodies that are payable in their primary stage have also been affected by secondary enrichment. This is conspicuously the case at Chuquicamata and also at the Nevada Consolidated at Ely, Nevada. In the latter case the paying ores were originally thought to belong entirely to the zone of secondary enrichment.

The second alteration referred to is the conversion of a considerable amount of the original sulphide ores into oxides, carbonates or native copper. The extent to which this conversion has taken place varies greatly in different cases and seems to be some function of the presence of lime in the original rocks. Thus in the presence of the true limestone the original copper does not appear to migrate but is converted into a new carbonate practically in situ. In cases where the granite rocks in which the dissemination has taken place contain a good deal of lime-bearing feldspar, the copper has migrated and secondary enrichment has taken

place, but at the same time large amounts of copper have been fixed in the form of carbonates. These carbonates generally overlie the sulphides of the zone of secondary enrichment making a kind of shell, not usually very rich in copper but containing on the aggregate enormous amounts of it. In the case of the Ajo deposit a formation of carbonates was produced affecting about 15 per cent. of the original mass of ore, this being the superficial portion of it, without any leaching or secondary enrichment whatever. Thus the oxidized portion lies immediately upon the mass of primary ore and there is no difference in the content of copper between one and the other.

The importance in a commercial sense of the formation of these oxides lies in the fact that they do not concentrate in the same manner or on the same terms as the sulphides. A certain amount of them can be recovered by the ordinary process of water concentration but the recovery is not good for the reason that the carbonates and oxides are usually fragile and easily pulverized and the specific gravity is rather low so that the finer particles are usually carried off. In addition to all this the masses of disseminated carbonates are usually pretty low grade, not often being above 1.25 per cent. copper so that a low recovery by concentration does not leave enough copper to make it pay. However, the enormous quantities of such materials so easily accessible, being frequently right on the surface without any barren covering at all, has made it a great object to find a process by which such copper could be secured. This problem has been solved in two cases; namely, those of Ajo and Chuquicamata, by using a leaching process by which the copper in the oxidized ores is taken up by a solution of sulphuric acid and re-deposited either on iron or by electrolysis.

This is thoroughly workable but it has the same disadvantage as the process of water concentration, in the fact that it is available only on the oxidized ores and does not deal with the sulphides. It happens that a good part of the ore bodies are mixed oxides or carbonates and sulphides. Up to date no process has been discovered that handles these adequately, but I believe that various experiments, some of which are being conducted by the Bureau of Mines, are promising enough to lead to expectations that this problem also will be solved in commercial terms.

This, I think, is a fairly comprehensive description of the broad features of these deposits, both as to their geological origin and their commercial occurrence. It remains to mention the quantities of such ores that have been developed and to discuss the financial results of their exploitation. It should already be clear that such ore bodies vary within considerable limits both as to their original content of copper and in the content as determined by secondary enrichment and oxidation. Thus in almost every case certain portions of the ore will be found to run as much as 3 per cent. but the other portions grade down to only 0.5

per cent. The amount of ore available is an irregular function of the grade that is required. In the earlier stages of the development it was not believed that ore much under 2 per cent. would pay, therefore attention was directed specifically to such portions as would run more than that, but after large plants had been established running from 5,000 tons a day upward, mining being done by steam shovels or some other wholesale method, two things were found out; first, that money could be made from ores running a good deal less than 2 per cent. and, second, that it was a practical impossibility to keep ores that would run 2 per cent. or over, separate from certain enclosing or intervening masses that would not run so much. Thus as a practical matter it was found that the mass of material to be worked was inevitably much in excess of the amounts estimated at the initiation of the enterprises and it was the equally universal experience that the grade of ore sent to the mill was markedly lower than the grade originally estimated. The emergence of the latter fact was noted by some of the operators at first with dismay and in some cases they even hesitated to disclose their figures regarding tonnage treated, hoping, no doubt, to overcome the difficulty before the knowledge that there was a difficulty would alarm the public, which was the general backer of all these enterprises. Part of the rather disconcerting low grade of the ore milled was due also, no doubt, to the fact that the concentrating process failed to give as good a recovery as was expected. But after all, the outcome proved that the disappointment in yield per ton was a negligible difficulty, in fact no difficulty at all: first because the operating costs were low enough to make a good profit on the ore as it was; second, because it was possible to increase the tonnage treated far beyond the amounts originally intended, and third, because the lowering of the grade was compensated several times over by the increased volume both of ore and copper made recoverable by added explorations and by taking lower-grade ores into the definition of availability.

It may be said that the commercial success of the porphyry mines is almost invariably greater than the original expectations, but this fact is derived from compensating factors that have been superior to the disappointments. The value of a mine, of course, is very largely a matter of income, and this income is dependent on the output of copper. If twice as much copper is produced as was originally intended at the expense of handling three times as much ore in order to get it, the income of the property is still nearly or quite twice as much as was originally contemplated. This will depend, of course, on the cost of operating, but with increased tonnage the costs usually go down in some proportion. In a general way this is exactly what has happened with most of the mines. In 1906 the Utah Copper Company expected to produce 50,000,000 pounds a year and get a yield of say 26 pounds of copper per ton. In 1909 it expected about 75,000,000 pounds and got about 18 pounds per

ton. In 1916 and 1917 it has actually been producing more than 200,000-000 pounds from ores yielding some 17 pounds of copper to the ton. The costs have never been quite so low as were hoped for but the difference has never been very great and the income has been several times greater; and not only that, the expected life of the property by the constant addition of further ore supplies has remained as long as ever.

To take another example, the Miami Copper Company in its prospectus issued in 1908 planned for a mill of 1000 tons a day, expecting a yield of 40 pounds of copper per ton and an annual production of 14,000,000 pounds. As a matter of fact its yield per ton, in spite of all efforts to keep it up, has not been over 30 pounds, but the milling has lately been done on a scale of more than 6000 tons a day and the output has been over 60,000,000 pounds a year, the costs being not much, if any, above those originally calculated upon. This we may say is the general experience of this type of property. At present it is very hard to say whether the maximum output has been reached or not. The high prices and forced production during the war period may have brought many of them up to the maximum output which sound economic policy would justify, but undoubtedly many of them have not yet reached that point. Thus, it will appear that from the standpoint of making money the controlling factor has really been the development of plants and equipment which, of course, means the investment of capital enough to make a very large output.

During the ten years which have elapsed since the information was gathered for the first edition, several developments in industrial methods have taken place which have been exceedingly valuable to the operation of the porphyry mines, more particularly perhaps in their case than that in any other kind of property. Without laying stress on the number of small things that might be mentioned, such as improvement in rock drills and similar mechanical devices which have contributed something, the main factors have been first, a development of the oil flotation process; second, the development of crushing machinery, particularly ball mills; these have not added much of an improvement in the matter of operating costs over devices formerly employed but have facilitated the fine crushing of enormous quantities of material by machines occupying very small spaces. As an example of this it may be cited that the Miami mill as originally built was intended for a capacity of 2000 tons a day; it has since been modified so that 6000 tons a day are being put through it, but the neighboring Inspiration mill, originally designed to take advantage of the possibilities of economizing space through the use of ball mills, with a floor space no greater than that of the Miami mill which be it remembered was designed for 2000 tons in 1909, puts through regularly 18,000 tons of ore per day. How much economy of operating expense there may be in this economy of space is perhaps

difficult to figure out, but is is probably considerable. What is perfectly patent is that there is an enormous saving in plant construction. Third, a continued development in the general practice of substituting mechanical power for labor. This is done not so much by special devices for economizing labor as by utilizing power on a large scale and producing power cheaply. This might be illustrated from several other forms of mines fully as well, perhaps better, than in the porphyries. The utilization of power results in great savings through securing a large output from single units. Thus at present the usual practice is to get out several times as much ore from a single shaft as was done ten years ago. A conspicuous example is the Inspiration mine where a single shaft equipment employing no more men to run it than the ordinary shaft provides for the hoisting of 20,000 tons a day. The same thing has been done in southeast Missouri where ten years ago 300 tons a day was considered a respectable output per shaft; now 1000 tons per day is only a fair output and a new equipment would probably provide for from 2000 to 4000 tons. The power required to hoist a ton at increased output remains as great or almost as great as ever, but the equipment of one shaft both in material and personnel is hardly more than one-fourth of the equipment of four shafts. The result is a greatly increased output per man per day. Another example of the same process is the development of a large type of steam shovel which is being used in the Lake Superior district and perhaps among the porphyry mines. This new type of shovel weighs about 350 tons. Before its introduction about the largest machine in use was the 90-ton Bucyrus shovel. I understand there is little or no economy in operating the shovel itself; but here is the economy: The big shovel removes a cross-section 11 times greater than that of the 90-ton shovel. Since every time the machine is moved a railroad track has to be moved, it is evident that the big machine can be operated at one-eleventh the former amount of track construction; and that is a very considerable item in the whole process.

These are illustrations of the general principle which I think has had the greatest effect in the organization of industrial enterprises in the past 10 years. Its effect in the way of reducing costs, or of increasing the output per man, which is the same thing, has in many cases been very great indeed. For instance, at some mines in southeast Missouri, which are not porphyry mines but are a convenient illustration, the cost of power in 1912 was about 35 cents a ton of ore milled. In 1916 this had been reduced to about 10 cents. Concurrently the output per man per day in these properties, perhaps not within the period of time just mentioned but approximately so, was doubled.

I have not dwelt upon the flotation process as much as it deserves. Its introduction into this kind of mines dates later than the first edition of this book. I can do little more than point out the general effect of

it for one very good reason: that I know very little about it as a technical matter. The process has been in a state of perpetual evolution or development. Even in cases where the theoretical possibilities are pretty well worked out their practical application has not been always perfected. In almost every case there still remains a field for the introduction of supplemental processes which will take care of carbonate ores not adequately dealt with by the flotation method, and also of the mixed carbonates and sulphides referred to above. But in many cases the use of flotation has been a tremendous improvement over anything that was possible before, both in the recovery of metals and in the economy of space and reduction of costs. Thus it may be said generally that a sulphide ore can be made to yield easily 90 per cent. of its value by flotation. Most ores would not yield as much as 70 per cent. by the water concentration processes of ten years ago. The substitution of a process that will save 90 per cent. as against one that will yield only 70 per cent. means an increase of 30 per cent. in the output of metal. This is a matter of overwhelming importance. It is precisely in the matter of practical adjustments required to make an actuality of this improved recovery that much remains to be done. In a great many mines the improvements made possible by flotation are only about one-half realized on account of certain mechanical and constructive difficulties. Thus in some mills it has not been very easy to substitute finer grinding, which is required for flotation, for the crushing machinery already installed. The result is a sort of compromise which admitted of a large increase of production at very little expense. To obtain the remaining increase which is patently possible there is sometimes the necessity of going to great expense, perhaps the construction of an entirely new plant. In many cases this would pay but there are often good reasons for not introducing such a project at once. For instance in times of acute demand for the product it is not always easy to get the machinery or labor to make the installation. To introduce such a project might hamper the present working of the mine. Then again in some cases the material rejected is not finally lost but remains available for future working in the form of tailings or slimes, which are generally impounded. Still further there is often a complication involved in the fact that the technical details of finished operation are just being found out and it may often seem desirable to postpone the construction of a thorough plant until further progress has been made in the art. Almost every mine of any importance in the world is an example of one or all of these considerations. It is fair to say that a great many changes in milling practice, recognized as feasible and desirable, have not yet been executed. Unquestionably the results that would be obtained from this field are more important than the pecuniary returns of any particular property, for they will open up or make available a considerable addition

to the visible reserves of copper and other metals. To put the thing concretely, the Utah Copper Company is making an output of 200,000,000 pounds a year, and in order to do so it is milling 13,000,000 tons of ore a year containing about 325,000,000 pounds of copper. Thus 125,000,000 pounds are permanently, or temporarily, lost through milling and smelting losses, the net recovery being about 62 per cent. A substitution of the recovery of say 85 per cent. would mean an additional output of about 75,000,000 pounds of copper a year. If we apply the same figures to the whole amount of ore as it originally stood, say 400,000,000 tons, the improvement in recovery would put an addition of more than a million tons of metallic copper in sight. Be it remembered that this amount is 4 times the amount of copper estimated to be commercially available on this property in 1906. And this is only an example of the state of affairs in the whole field of disseminated copper mines.

I would not refer to this matter with any emphasis were it not for the fact that the recoveries thus indicated are known to be thoroughly possible and are not visionary calculations by any means. Some failure to secure all the metal that there is in an ore is generally taken for granted in mining practice. It is not a matter of practical importance whether the recovery is only 60 per cent. or not so long as there are no known means of improving it, but the flotation process with the subsidiary processes that are being developed to supplement it does permit a vast improvement in mining practice and of course it is a new element introduced in the mining industry.

The resources of the "Porphyries" constitute a large part of the visible source of this metal. A list of 17 of these mines, not a complete list but nearly so, compiled by L. H. Taylor, Jr. is given below. I have not examined critically the facts which support these figures. Certain allowances must be made in some cases that I happen to know of for the inclusion of ores that are certainly copper bearing but not certainly profitable; but whatever its shortcomings it is fair to believe that the table give a pretty good idea of what to expect of these mines. I imagine that before they shall have been entirely abandoned they will have produced approximately the amounts set down.

The estimates are confessedly too general to make it worth while to add up a total for the amounts, but roughly we come to an estimate of some 1,950,000,000 tons of ore which is expected to produce 56,000,000,000 pounds of copper. If the estimates are at all reliable such a yield is not incredible in view of the high recoveries made possible by the flotation process. But by past experience we should not expect so much, say rather about 20 pounds per ton, or a total of about 40,000,000,000 pounds. It is well to notice also that more than half of all this ore is in Chile.

If this estimate is worth anything we are assured of the world's supply of copper for 20 years from this one group of mines.

ORE RESERVES—PORPHYRY COPPERS

Company	Ore reserve, tons	Average grade, per cent.	Recoverable copper in ore reserve, pounds	Capacity, daily tonnage	Life of mine, years
Andes Copper Mining Co.	110,000,000*	1.40*	2,400,000,000	15,000z	21
Arizona Bagdad Copper Co.	20,547,500	1.44	503,002,800	3,000z	19
Braden Cop. Mines Co....	263,506,356	2.255	9,954,000,000	6,000	75‡
Burro Mount. Cop. Co....	3,835,000	2.20?	121,492,000	2,000	5½
Canada Cop. Corp., Ltd...	12,000,000	1.74	328,657,200	3,000	11½
Chile Cop. Co............	697,510,349	2.12	24,300,000,000	11,500	74†
Chino Copper Co.........	96,552,026	1.63	1,992,000,000	12,500	22
Con. Coppermines Co.....	19,653,034	1.33	430,240,000	1,000	11½x
Howe Sd. Co. (Brit. Mine).	9,787,396	2.16	295,970,000	2,500	11
Inspiration Con. Cop. Co..	82,754,277	1.63	1,970,000,000	20,000	11½
Miami Copper Co.........	54,570,000	1.467	1,139,000,000	6,000	26
Nev. Con. Cop. Co........	68,549,644	1.57	1,448,000,000	13,000	15
New Cornelia Cop. Co.....	51,320,421	1.58	1,317,800,000	5,000	29
Ohio Copper Co. of Utah..	15,000,000	0.80	177,600,000	3,000	14
Ray Con. Cop. Co........	86,383,642	2.061	2,667,000,000	10,000	24
Ray Hercules Cop. Co.....	9,500,000	1.77	269,000,000	1,500	17½
Utah Copper Co..........	374,040,000	1.37	6,672,900,000	40,000	27

x At enlarged capacity of 5,000 tons daily.
‡ At enlarged capacity of 10,000 tons daily.
† At enlarged capacity of 27,000 tons daily.
z Proposed.
* Estimated.

I include the following sketches with no pretension of describing this business in detail, but merely with the hope of illustrating the growth and broad economic features.

Miami Copper Company.—The following prospectus was issued in March, 1908:

"The property of the Miami Copper Company consists of about 300 acres, 200 of which is mineral land, located six miles west of the city of Globe, Arizona, at which city are the mines and works of the well-known Old Dominion Company.

"Development which is still being carried on shows to date 2,000,000 tons of concentrating ore containing 3 per cent. of copper. Ore was struck at a depth of 220 ft., and the bottom of the shaft, at a depth of 500 ft., is still in ore, and the area shown of the ore body is 300 ft. by 350 ft., without having as yet reached the limits, so that the prospects are that an enormous body of concentrating ore will be developed as indicated by surface conditions.

"The Gila Valley Globe & Northern Railway ends at Globe, six miles distant, and surveys past the Miami have been made and right of way secured; this extension will pass within a quarter of a mile of the mine. There is abundant water available for concentration purposes.

"It is proposed to erect the first unit of a reduction works, which unit will have a daily capacity of 1,000 tons. This will give an annual production of 14,000-000 lb. of copper, based on 350 days running time an a yield from the 3 per cent. ore of 2 per cent., or 40 lb. of copper to the ton.

Concentrating tests have shown that the ore can be readily concentrated 10 into 1 and the resulting concentrate smelted with the above yield in fine copper. It is estimated that the cost of electrolytic copper sold in New York will be 9 cents per pound. On this basis the profits at 12 cents copper will be $420,000 per annum, and at 15 cents copper $840,000 per annum. As developments advance a second unit of 1,000 tons daily capacity will be built which will double the above figures of profit.

"It is estimated that it will require $750,000 to erect the necessary first unit of the reduction works and that $250,000 additional will be required for mine plant, shops, buildings, etc.

"The ore deposit of the Miami Copper Company is in nature similar to those of the Arizona Copper Company, the Nevada Consolidated Copper Company, the Utah Copper Company, and the Boston Consolidated Mining Company; that is, large masses of ore in which the copper as a sulphide mineral is disseminated through the rock and which readily yields a high-grade concentrate by water treatment, which can be easily smelted.

"The mining is simple and cheap and when found these deposits are the most valuable as copper producers. The Miami ore, running 3 per cent. in copper as it does, is higher in grade than any of the above-mentioned properties and it will without doubt prove a large producer and dividend payer."

During the year which elapsed after this was issued all hopes have been far exceeded. There are now 13,300,000 tons of ore in sight and the company is erecting a plant of 2,000 tons daily capacity which is twice the original plan. It is hoped that this plant will begin operations in the summer of 1910.

The first six years of operation showed the following results;

PRODUCTION

Year	Tons milled	Pounds copper	Pounds per ton	Price per cents pound	Receipts in dollars
1911........	445,036	14,970,557	33.6	13.00	1,950,669.45
1912........	1,040,744	32,477,923	31.2	16.60	5,385,501.53
1913........	1,058,784	33,134,334	31.3	15.25	5,049,807.04
1914........	1,096,633	32,879,447	30.0	13.40	4,389,026 30
1915........	1,348,122	41,907,754	31.1	17.30	7,262,884.02
1916........	1,842,017	54,433,863	29.5	24.00	13,072,440.06
6 years......	6,831,336	209,803,878	30.7	17.67	37,710,328.40

For the five years preceding 1916, the average price of copper was 15.5 cents; and during this period there had been no unprecedented prices.

The dividends paid during the six year period amounted to $9,695,783.75.

In addition to this the quick assets had increased over the beginning of 1911 as follows:

	1911	1916	Increase
Ore	$232,410.11	5,419,055.75	$4,790,873.12
Metals	395,772.52		
Supplies	182,389.78	346,439.22	160,049.44
Stock	21,661.88	101,762.28	80,100.40
Cash	85,670.68	1,525,109.03	1,439,438.35
Total	$917,904.97	$7,392,366.28	$6,474,461.31

Combining dividends with the increase in quick assets we have a total profit of $16,170,245.06, equal to 7.7 cents per pound. The apparent cost remaining is $20,940,083, equal to 9.97 cents per pound copper and $3.05 per ton milled.

Chino Copper Co.—An Open Pit Mine. "The original issue of first mortgage bonds amounted to $2,500,000. During the year 1912, $185,500 par value were converted into stock; during the year 1913, $2,078,000 par value were converted; during the past year all of the remaining outstanding issue amounting to $236,500 par value, $235,000 were converted into stock and the remaining $1,500 par value were paid for in cash: thus retiring the entire issue." (Report of the President, C. M. McNeill, 1914).

Year	Deferred charges	Construction and development	Working capital	Mining property	Tons	Pounds copper
1911	$541,417	3,760,015	$640,000	$1,802,795	40,000	986,375
1912	867,382	4,646,920	2,359,492	1,913,719	1,120,375	27,776,088
1913	1,315,454	5,580,216	298,521	1,916,456	1,942,700	50,511,661
1914	1,799,632	6,095,395	2,427,710	1,918,101	1,907,300	53,999,928
1915	2,160,158	6,634,690	5,747,130	1,924,084	2,379,800	64,887,788

Year	Dividends	Receipts from metals	Miscellaneous income	Interest
1911	....	$131,232	$85,223	......
1912	$1,919,070	4,344,261	125,133	$160,397
1913	$1,919,070	7,621,419	137,533	69,862
1914	2,169,065	7,247,197	179,588	31,832
1915	2,609,860	11,383,777	229,074	3,819

In all 99,940 shares of stock were issued to convert the bond issue, leaving the outstanding capital stock at 869,940 shares.

In 1910, the amount raised in cash for stock seems to have been	$1,860,000
1911, First mortgage bonds and notes payable	2,700,000
1912, Stock issue of 70,000 shares at $25	1,750,000
Total cash for plant and working capital	$6,310,000

At this date total investment was about $7,900,000 so that about $1,600,000 had been added from the production of the mine. By the end of 1915, the total capital accumulation was as follows:

Deferred charges to operating (stripping)	$2,160,000
Construction of plant, and development	6,634,690
Balance of quick assets	5,747,130
Total	14,541,820

If from this total we deduct the $6,310,000 raised by stock subscriptions and conversions, we have left $8,311,000 raised by operating, of which $5,747,000 was liquidatable. There remained nearly $2,500,000 that had been put into plants, some of which ought, probably, to be charged off to depreciation. To make a rough guess let us suppose that one half, say $1,300,000 should be so charged off. We should still have remaining a surplus for the period of about $7,000,000. Add to this the dividends and we have total actual profits about $13,700,000 from a net output of 198,160,000 pounds copper, equal to about 6.9 cents per pound. There was paid in addition $265,910 for interest on bonds, etc., which would not have been necessary had the enterprise been completely financed, so that this amount also was paid from earnings, bringing the total earnings up to full 7 cents per pound. The total receipts from metals were $30,727,886 equal to 15.5 cents per pound, making miscellaneous receipts $756,551 or 0.38 cents per pound, making total receipts 15.88 cents per pound. Deducting net profits of 7 cents we have a total cost of 8.88 cents.

Ray Consolidated Copper Co.—An Underground Mine in Arizona. This concern became a copper producer in April, 1911 and since then has had the following record.

End of	Net copper	Tons milled	Construction equipment after depreciation	Mine development	Net working capital
1911	14,935,047	681,519	$5,743,929	2,120,491	842,000
1912	34,674,275	1,565,875	6,514,675	3,024,613	1,364,004
1913	52,341,029	3,365,296	6,537,514	3,737,342	1,505,871
1914	57,004,281	2,427,700	6,347,846	4,024,120	1,970,236
1915	60,338,936	2,848,969	6,495,274	4,076,250	4,055,093
	217,293,568	9,889,359			
1916	74,983,840	3,332,340	8,001,332	4,655,381	9,694,492
1917	88,582,649	3,560,900	7,927,277	6,044,968	11,167,217
	380,859,757	16,782,599			

Several points in this record are worth noting with reference to general principles; first the steady growth of tonnage treated and copper produced for six years after the plant was started: second the equally steady growth of the capital invested in construction equipment and development: third that the increase of such capital did not keep pace with the output, but decreased from $6 per ton milled and 28 cents per pound of net copper produced in 1912, to less than $4 per ton milled and 16 cents per pound of copper in 1917.

Another point worth attention is the growth of working capital and surplus. Up to 1915 this growth barely kept pace with the output of copper and there is reason to suppose that the company was during this time straightened for funds, for at the first good opportunity, 1915, when the price of copper averaged 17.5 cents a pound without any increase of working costs, the amount set aside for working capital or held in quick assets was immediately doubled. I think we are justified in believing that under the pre-war conditions 4 cents a pound of annual production was the lowest permissible working capital. It is probable that 6 cents a pound was comfortable. But when the price of copper mounted to over 26 cents in 1916 the company held 13 cents pound on its annual output for this purpose and continued to hold it through 1917.

Just what reasons actuate a concern in holding a large surplus of quick assets are not always clear from its reports. The inescapable reason for a certain amount is of course, the actual necessity of having enough money to meet current operating expenses and to carry the product through the process of mining, milling, smelting, shipping and refining until it is sold; but other reasons supervene. It is not uncommon for a mining company to acquire a surplus of funds for purposes not always definite in the minds of the directors, as for instance a general intention of buying further mining property, of rebuilding plants, of providing new ones or of exploiting new processes. Still another reason comes to the front during periods of economic or political disturbance—the desire to hold funds as a protection against unforeseeable demands. During the past two years for instance, the nature, amount and settlement of war taxes has given rise to much painful uncertainty and withholding of dividends.

In the case of Ray Consolidated the amounts I have set down for working capital are the net current assets.

The experience of Ray Consolidated, illustrates the fact that the completion of a plant, according to its initial design, does not put an end to plant expenditure by any means, but that so long as production is increased plant must be increased also. At the end of 1911 this plant was ready to make an output of 35,000,000 pounds, from 1,565, 000 tons of ore in 1912. The capital invested in plant and development was then $7,860,-000. By the end of 1917 an output of 88,582,000 pounds from 3.560.000

tons of ore had been reached, but the plant and development account then stood, including depreciation, at $13,972,000—an expenditure of $6,000,000 during a period of six years in which about 360,000,000 pounds had been produced. The increase of plant cost therefore 1.66 cents a pound of copper produced.

If we assume that 6 cents per pound of annual production is a fair allowance for working capital we should have to estimate not less than $3,200,000, or about 0.088 of a cent a pound would have to be held for that purpose, out of earnings. The total amount required for new capital was therefore about 2.56 cents a pound over the whole period.

With these data in mind we may make a fair estimate of the normal operating costs and profits of the enterprise. For this purpose it seems best to take the record only to the end of 1915, a period during which prices had not reached any abnormal heights. For that period we find that 217,293,568 pounds of copper, with a small amount of gold and silver had been marketed for $33,426,525.48 equal to 15.38 cents a pound. About $3,200,000 was added to working capital, $3,600,000 added to plant, and $4,593,000 paid in dividends, making a total of nearly $11,400,000, or 5.25 cents a pound, leaving a gross operating cost of 10.13 cents a pound.

It seems, however, fair to question the accuracy with which various capital accounts are transferred to operating.

In 1911 the indebtedness in bonds and notes payable was $3,950,000 and the capital stock $11,991,750. In 1915 the indebtedness had been reduced to nothing, but the capital stock had been increased to $15,712,790, an increase of $3,721,040; and a surplus accumulated from sale of securities of $1,451,835, making a total increase of $5,173,375. If from this we deduct $887,691.19 paid as interest on bonds, notes and advances during this period, we have a remainder of $4,305,683.81 net from these sources. A part of the increase of capital was due to the purchase of the Ray Central Copper Co. in 1912, but the reports leave us in the dark both as to the number of shares issued for that property and the amount of cash it had in its treasury.

We find further that an item of $1,606,971.36 came in as "miscellaneous income" which must be accounted for, no doubt, before the total expenditures can be ascertained. In all it seems that the company had receipts from outside sources of nearly $2,000,000 beyond the amount required to call in the bonds and pay interest on them. It is next to certain that this amount was more than sufficient to cover the purchase of Ray Central.

The reserves for depreciation seem low, amounting at the end of 1915 to only $878,500 for five operating years and at the end of 1917 to $1,635,784 for seven years, an average of only $231,000 a year. It is true that for five years the capital charged to plant and equipment was

held nearly at level by means of the depeciation charges, that during this period the tonnage treated increased materially, and that the railroad, power-plant and shops had probably not depreciated at all, perhaps even enhanced in value; but it is more than probable that the milling plant had suffered a very great depreciation and that a fund should have been started for rebuilding it. It is not, indeed, certain that the plant was not capable of maintaining the performance upon which this financial record is based. The need for reconstruction arose through the development of a new and superior mill design and practice through the exploitation of the flotation process. The need for a new mill was based therefore on the expectation that it would more than pay for itself by better recovery and cheaper operation. So long as we are discussing the cost of actual operations in themselves, it is unreasonable to add to them the cost of a different scheme of operating. There remains, however, the probability that with increasing age the expense of maintaining the plant at its original level of efficiency would increase and I am inclined to doubt whether it would be safe to count on anything short of replacing a milling plant entirely in ten years. I should be inclined to argue that a depreciation charge of six per cent. on the entire cost of construction—railroad, power-plant and all would not be excessive; would not in fact be anything more than anticipating expenditures sure to be made if the plants were to be kept indefinitely in operation. If this is true the total amount chargeable up to the end of 1915, should have been double what was actually charged and we should be justified in adding nearly $900,000, or say 0.4 cent per pound for additional depreciation.

In the matter of mine development also the figures argue apparently for higher charges than have been estimated Without going into an analysis of figures, it appears that for the history of the mine to date one foot of development was required for 50 tons extracted, but that on account of the reserve of broken ore created by caving the pillars, the amount of development work destroyed is greater in the earlier stages of operating the mine than in later stages. The smallest amount of development openings destroyed has been in 1916 and 1917—one foot to sixty tons. It remains, therefore, a question whether to charge development work at the rate of sixty, or only fifty, tons per foot. Under pre-war conditions the development work averaged $10.50 per foot, so that we are brought to an estimate of from 17.5 to 21 cents per ton. Up to the end of 1915 this estimate would amount to $1,750,000 to $2,100,000 against $1,113,273 actually charged. Thus we should charge $600,000 to $1,000,000 additional: striking an average, say 0.4 cent per pound copper.

If we are to consider this plant as having reached a level at which its output will remain stationary at about 80,000,000 pounds a year, we might expect the performance under pre-war conditions to be about as follows:

	Per ton	Per pound
Operating cost—Mining, milling, smelting, etc	$2.22	10.13
Additional depreciation of plants	0.09	0.40
Additional allowance for development	0.09	0.40
	2.40	10.93
Less miscellaneous income	0.09	0.43
Net cost application to dividends, say	2.31	10.50

According to the costs prevailing in 1915, a division of the net costs would seem to be about as follows—Mining 80 cents, milling 60 cents; smelting, refining and marketing 90 cents. It is to be noticed that the last item averages 4.1 cents per pound of copper, this from concentrates running 18 to 20 per cent copper. This is much higher than the direct cost of smelting, etc., to other companies that produce concentrates of similar grade, but it must be remembered that the cost of building and maintaining a smeltery has been saved, and there is no reason to suppose that the result is unfavorable to the mining company.

Moctezuma—Old Mexico.—This mine has far outstripped the expectations held out for it in the Phelps-Dodge prospectus of 1909.

	Tons	Copper	Development, feet	Grade per cent. ore	Earnings	Dividends
1909	510,094	26,119,000	19,550	3.22	$1,104,454	$ 988,000
1910	447,555	22,602,000	21,596	2.99	480,690	1,143,009
1911	517,352	25,511,582	13,668	3.17	1,206,182	754,000
1912	596,600	34,194,000	31,431	3.49	2,735,060	2,118,569
1913	603,654	37,180,000	31,292	3.56	2,402,447	1,950,000
1914	500,000?	29,591,658	......	....	1,189,100	1,170,000
1915	424,027	22,889,885	7,572	3.41		
1916	715,070	36,062,201	23,252	3.27		
1917	750,897	38,186,451	33,823	3.18		
	5,065,241	268,336,777	182,189			

The number of employes is not given.

The value of gold and silver per ton under pre-war conditions was about 45 cents. The earnings in 1912 and 1913 were about 7 cents a pound, leaving a cost of about 8.4 cents per pound. Since the yield was very close to 60 pounds, the cost must have been about $5.50 per ton milled. The development work done is one foot for 25 tons. The costs

per ton seem fairly low. The freight and treatment per ton of concentrate could hardly be less than $10.00. The proportion of concentrate to ore is about 22 per cent. The cost of freight and treatment must be about $2.25 per ton of crude. This leaves about $3.25 per ton for mining, milling, depreciation and general expenses.

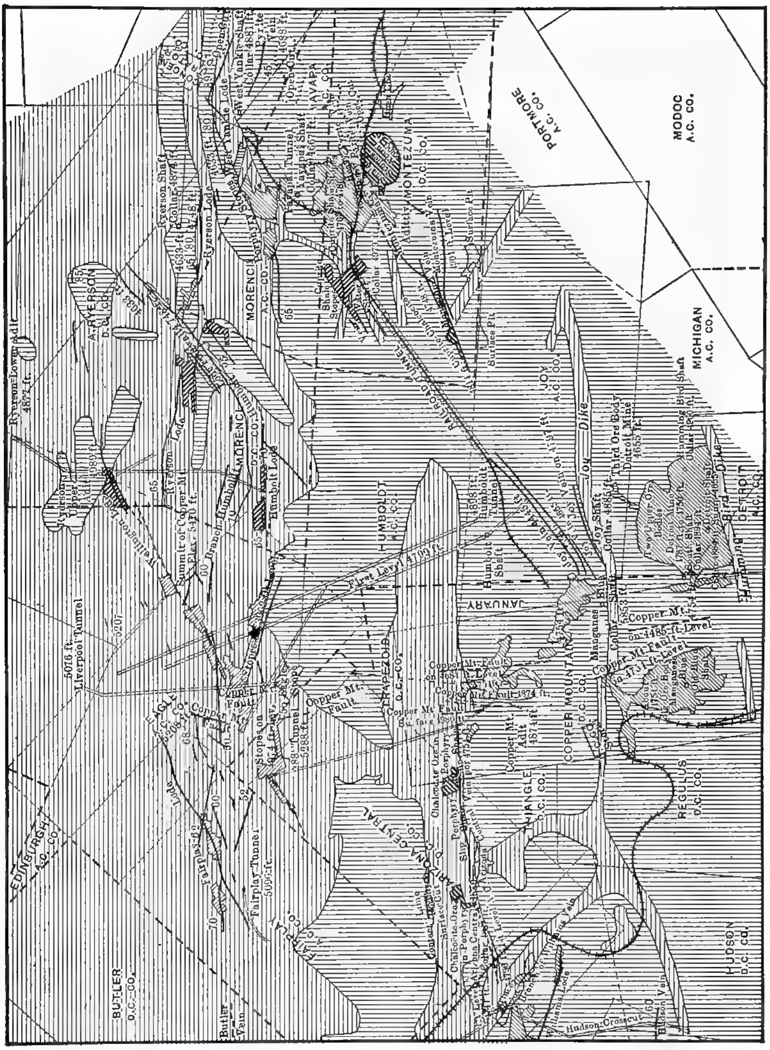


FIG. 6.—Arrangement of ore bodies in Clifton-Morenci district, Arizona.

How much these costs have been increased by the war is not indicated.

The mining industry of Clifton-Morenci has been much disordered of late years by prolonged and repeated labor strikes. The district has been producing less copper than formerly, or barely holding its own.

The ore has become lower and lower in grade until now it yields barely 40 pounds to the ton; all, or practically all, is disseminated in porphyry which, by the way, is, like the Butte batholith, or post-Cretaceous, or Eocene, age. For the successful conduct of this kind of an operation the early history of the camp is no doubt a handicap; for the mines were started and equipped on the smaller scale required to work mines of higher grade and it has been difficult to substitute the larger and simpler units of the modern "porphyries." The mining is all done underground. I am informed however, that the outlook of the distrct is not discouraging for large bodies of ore running between 1 and 2 per cent copper have been discovered in both of the principal mines. The following is retained from the first edition:

The Clifton-Morenci district produces prophyry ore in which chalcocite is disseminated. In this respect the orebodies resemble the deposits of Bingham, Utah, and of Ely, Nev. The ores form large irregular bodies at depths of from 100 to 300 ft. below the surface. In this respect the ore is easy to mine. But there is a certain irregularity, not only in the orebodies as a whole, but also in their internal make-up. A certain amount of sorting may be done to advantage in the mines. The ore is fairly hard and firm and is taken out by square-setting. Mexican miners with white bosses are employed.

The Cost of Mining

Costs are not generally stated in detail, but the reports of the Shannon and Arizona copper companies make plain the following facts:

About 1 ft. of opening work is necessary to find and develop 15 tons of ore. The cost of this work is stated to be 21 to 33 cents a ton (Shannon). Stoping costs are about \$2 to \$2.80 a cents a ton (Shannon). Stoping costs are about \$2 to \$2.80 a ton. Details for one year are shown in an accompanying table (p. 295).

The Arizona Copper Company gives its costs for mining, including deadwork, ores purchased, and leaching as follows: 1904, \$2.81; 1905, \$2.46; 1906, \$2.50. It seems fair to assume from this that the underground costs are substantially the same as the Shannon. The same may be said of the Detroit Copper Company.

Assuming that the cost of mining, including development, is \$2.25 to \$2.50 a ton, and that out of this cost about 50 cents is due to timbering, it seems fair to say that the excess over Lake Superior costs is due to the external factors.

The internal factors that govern the cost of treatment are the losses due to concentrating, the proportion of concentrates to the crude ore and the smelting qualities of the ore.

(1) The Shannon Copper Company reports for 1904 a saving of 75

per cent. on ore averaging 4.16 per cent.; in 1905, 73 per cent. on ore running 3.77 per cent., and in 1906, 69 per cent. on ore averaging 3.36 per cent. This saving is for both smelting and concentrating.

(2) The Shannon Copper Company smelted in 1905, 44 per cent. of its total output; in 1906, 44½ per cent.; in 1907, 56 per cent. The Arizona Copper Company smelted in 1904, 22 per cent. of its total output; in 1905, 20 per cent.; in 1906, 20 per cent.

The costs for concentrating, smelting, refining, and marketing are not given in detail, but in the case of the Arizona Copper Company these costs lumped together where, in 1904, $1.90; in 1905, $1.93; in 1906, $2.06, the costs being based on the entire tonnage sent from the mine. If the cost of concentrating is 75 cents a ton, including transportation from the mines, the cost for smelting, refining, and marketing would appear to be about $6 per ton smelted. On this basis the cost to the Shannon company, on account of the larger proportion smelted, should be $1.80 higher than to the Arizona company. This seems to be approximately the case.

(3) Certain difficulties have been experienced in smelting on account of a deficiency of sulphur for matting purposes. This is particularly the case with the first-class ores. In the earlier days this difficulty added more to the cost than it does at present.

Summary of Operations, Arizona Copper Company

	1904		1905		1906	
Total ore (tons)	491,600		547,000		610,000	
Total copper (lb.)	28,732,800		30,080,000		29,756,000	
First-class ore (tons)	31,695		26,000		31,378	
Concentrating ore (tons)	460,000		521,000		578,517	
Copper per ton (lb.)	57.5		56.3		48.8	
Tons smelted	102,893		108,000		121,507	
Tons leached	80,100		90,000		80,000	
Copper from leaching (lb.)	2,824,000		2,470,000		2,126,000	
Copper per ton from leaching (lb.)	35.3		26.3		26.7	
		Per Ton		Per Ton		Per Ton
Cost working mines (deadwork, ores purchased, leaching, etc.)	£285,056	$2.81	£276,326	$2.46	£ 373,560	$2.50
Smelting, refining, and marketing	£194,077	1.90	£215,846	1.93	£258,506	2.06
General	£14,286	0.14	£14,430	0.13	£15,579	0.14
Interest and amortization	£49,162	0.49	£58,965	0.52	£88,765	0.70
		$5.34		$5.04		$5.40
Cost per lb. at New York	9.3 cents		8.93 cents		11.07 cents	

SUMMARY OF OPERATIONS, SHANNON COPPER CO.

	1903–4	1904–5	1905–6	1906–7
Smelting ore (tons)	66,005	53,340	69,342	
Mill ore (tons)	91,311	135,503	140,683	
Total	157,316	188,843	210,025	209,654
Per cent. copper, smelted ore	5.28	4.70	4.37	
Per cent. copper, mill	3.34	3.41	2.86	
Per cent. copper, average	4.16	3.77	3.36	
Copper, lb. saved per ton	62.34	55.03	46.41	47.6
Per cent. saving	75.0	73.0	69.0	
Feet development	....	11,931	14,740	14,610

With these facts the experience of recent years is interesting by comparison.

DETROIT COPPER CO.

Year	Tons	Copper	Assay crude, per cent.	No. employees	Output per man per year, in pounds
1909	468,882	23,991,595	3.385		
1910	494,286	23,056,292	3.32		
1911	517,087	22,704,398	3.4		
1912	520,272	24,802,789	3.33	1414	17,540
1913	537,324	22,255,130	2.89	1510	14,835
1914	477,365	18,060,707	2.79	1438	12,560
1915	376,604	15,333,976	2.83	1307	11,800
1916	474,808	17,539,858	2.60	1241	14,000
1917	333,263	13,202,201	2.73	1192	11,000

The earnings reported were as follows:

Year	Earnings	Per pound, cents	Price, cents	Cost, cents	Dividend, dollars	Dividends per pound, cents
1909	$1,153,269	5.0	13.00	8.0	$760,000	3.25
1910	1,079,405	4.6	12.82	8.2	1,960,000	8.35
1911	930,495	4.1	12.36	8.25	800,000	3.6
1912	1,406,170	5.6	15.51	9.9	1,464,610	6.0
1913	1,112,870	5.0	15.37	10.4	780,000	3.45
1914	602,318	3.3	13.57	10.3	280,000	1.6
	$6,284,527				$6,044,610	

The statements of earnings have not been published since 1914. For the years 1912, 1913 and 1914 we may deduce the following:

Since the cost of freight refining and marketing was about 1.3 cents per pound (there being no gold or silver to speak of in the ore) the cost of producing, at the smeltery, would be about 8.6 cents per pound in 1912, 9.1 cents in 1913 and 9 cents in 1914. Multiplying the copper produced per man by the cost per pound we get the cost per man per year as follows:

1912	17,540 lb. at 8.3 cents	$1,455
1913	14,835 lb. at 9.1 cents	1,350
1914	12,560 lb. at 9.0 cents	1.130

If the labor cost was 60 per cent. of the total, we would conclude that the average earnings per man in 1912 were about $870, in 1913, $810, in 1914, $700. In all probability the earnings did not vary as indicated but were more likely at an average of the different figures, say about $800 per year.

The output per man is very low, being only 35 to 50 pounds per day against 100 pounds at Bisbee and nearly 200 pounds at the Inspiration for the same kind of operations. Whether the low wages are the cause or the effect of the low output I do not know. One thing is very certain—so long as the production per man is on the present scale, the wages in this district must remain lower than in the other districts of Arizona. If the wages are to be the same as in other camps, the business will have to be reorganized radically and the output per man doubled. Probably this situation is at the bottom of the strikes. The miners can hardly be expected to understand these things; they merely rebel against the disparity of wages which appears to them as an injustice.

The same general facts hold true with the Arizona Copper Co. where in 1916 the output of copper per man was only 50 pounds per day.

Nevada Consolidated Copper Co.—This is an example of a steam shovel mine of fair grade. From 1909 to 1915 inclusive 18,473,000 tons yielded 415,848,000 pounds of copper, the average value of which with included silver and gold was 15.34 cents a pound, giving a total value of about $63,660,000, of which however, only $58,456, 000 had been realized.

Profits may be expressed as follows:

Dividends paid	$19,975,000
Increase of quick assets	4,000,000
Increase of deferred assets	4,000,000
Total	27,975,000

This is equal to 6.72 cents a pound, leaving an apparent cost of 8.62 cents. The yield was about 22.5 pounds per ton, giving a total cost of about $1.96.

In 1915 the costs were:

				Per Ton
Mining....................3,081,520 tons			$1,308,211	$0.425
Freight..................................	$ 825,072			
Milling..................................	1,641,517			
Smelting (about 520,000 tons).............	1,237,255			
Depreciation............................	493,043			
	4,196,887			
Less profit..............................	764,918		3,431,969	1.114
	3,431,969			
Freight and Refining..........................		$926,634		
Commission...................................		112,858	1,039,492	0.337
				$1.876

SUMMARY OF STATEMENTS

Nevada Consolidated Copper Co.

	Deferred charges	Property and development	Working capital	Tons	Pounds copper
1909	$ 140,784	$9,476,309.53	$2,510,000	1,065,387	34,527,823
1910	1,179,111	17,134,222.42	2,633,617	2,237,028	62,772,342
1911	2,117,361	17,077,330.34	2,241,872	3,338,242	78,541,270
1912	2,738,075	16,748,381.60	3,324,236	2,852,515	63,063,261
1913	3,276,397	14,256,068.76	3,249,897	3,139,137	64,972,829
1912	3,739,987	13,361,672.36	3,191,444	2,640,294	49,244,056
1915	4,136,970	13,027,218.83	5,732,521	3,081,520	62,726,651
				18,473,011	415,848,232

By the end of 1918 dividends had increased to $42,275,000, being $23,300,000 in the three years of high prices, from an output of about 249,000,000 pounds from 10,800,000 tons equal to more than 23 pounds per ton. The profits applicable to dividends were therefore about 9.5 cents per pound. The costs, figured on the basis given above, were about 10 cents a pound in 1916, 13 cents in 1917 and over 15 cents in 1918. Up to the end of 1917 the total receipts had been $113,171,000, from which $37,000,000 were available for dividends. This was from 491,323,000 pounds sold at an average price of 18.3 cents. The net profit therefore was 7.5 cents and the gross cost 10.8 cents. It will be noted that the gross receipts exceed the value of the copper by a large margin.

Utah Copper Company.—This has been for some years the greatest individual copper mine, and it has always been the greatest of the "porphyries," although it appears that the Chile Copper Co. has, at Chuquicamata in Chile, a still larger one. But with a tonnage in sight reported at 375,000,000 and a plant capable of treating more than 12,000,000 tons a year, it has a long life and a high earning power. The yield per ton seems to average about 17 pounds. The average operating profits seem

to have been up to the end of 1915, about 5.0 cents per pound, half of which was absorbed in capital, fixed or working. From 1908 to 1915 inclusive about 760,000,000 pounds had been sold for $115,420,000, equal to 15.3 cents per pound. This leaves an actual cost of about 10.3 cents

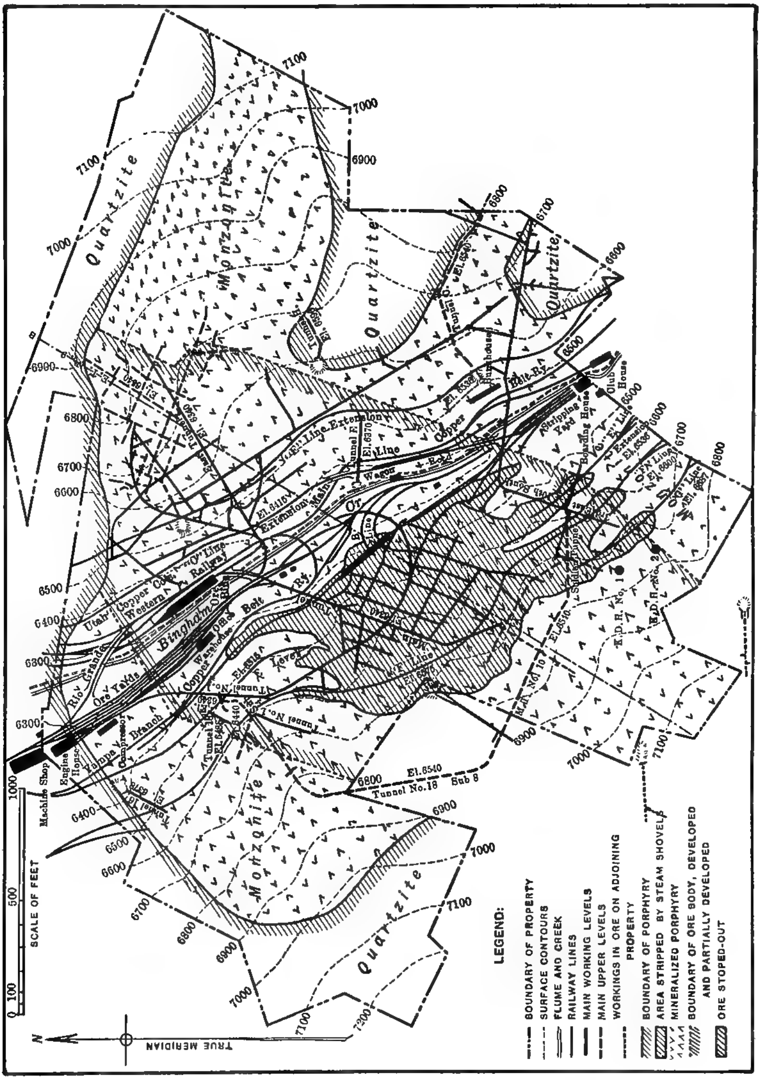


FIG. 7.—Property of Utah Copper Company, Bingham, Utah.

a pound. What the capital requirements for the future will be it is very hard to determine but it would seem as if this great enterprise should be nearly complete and that from now on a greater proportion of the profits should go to the shareholders.

It requires considerable analyzing to dissociate the affairs of the different parts of this corporation. It appears that the company owns a

trifle over half the shares of Nevada Consolidated Copper Co. From its own mine at Bingham it has produced up to the end of 1918 about 1,350,000,000 pounds of copper. Its total dividends were $92,000,000 of which presumably about $21,000,000 came from Nevada, leaving $71,000,000 from its own mine. Of this output 580,000,000 pounds were produced in the three years of high prices, and during those years the dividends were, from its own ores, about $51,000,000, or 8.8 cents per pound. For those three years the average price received for copper and associated metals was over 25 cents a pound. The "practical" costs therefore which include reserves for taxes and other emergencies must have been about 16 cents.

Utah Copper (in 1908).—The actual production for eighteen months ending December 31, 1908, was as follows, the figures being the net return free from all smelter deductions:

	Pounds copper
Copper metal	54,051,212
Gold, 20,072 oz. equal to	3,000,000
Silver, 163,953 oz. equal to	665,000
Total metallic output expressed in copper	57,716,212

Using the round number of 57,700,000 lb. as a divisor, we may calculate the cost as follows:

	Dollars	Approximate per ton milled	Per lb. copper, cents
Operation (mine and mill)	$2,666,284	$1.20	4.448
Mine development	20,028	0.01	0.035
Prepaid stripping	121,103	0.06	0.210
Freight on ore	658,754	0.32	1.142
Treatment and refining	1,806,659	0.85	3.131
Taxes, etc	7,588	....	0.012
Total operating	$5,280,416	2.47	9.134
Add depreciation, 6 per cent. of plant cost	387,000	0.12	0.670
Total cost	$5,667,416	2.59	9.804

The cost does not correspond to that reported by the company because, instead of deducting the gold and silver from the cost of copper, as the company does, I adopt the more logical method of calculating an equivalent for the gold and silver in copper metal and charging against the sum thus obtained the total costs. The addition of depreciation is absolutely essential. It is a matter of experience in such plants that about 6 per cent. must be allowed for renewals and changes that usually have the appearance of new construction.

Furthermore, in a theoretical calculation of complete costs we must

add the amortization of the plant. In this case there is a guaranteed life of twenty-five years. This means that the capital will be retired with 5 per cent. interest by an annual installment of 7 per cent. Now the total capital required for this business, outside of the cost of the land (which was probably nominal), averaged almost exactly $5,741,000 on which the installments for eighteen months would equal $592,805, equal to a trifle over 1 cent a pound. Add this to the 9.8 cents obtained above and we get 10.8 cents as the actual cost of copper to date.

Looking to the future it is not necessary to include the amortization in the calculation of dividends. It is, however, a vital necessity in calculating the cost at which the mine can sell copper, for if the owners were to sell copper, to take this example, at say 10½ cents, because they calculate an operating cost of 9.8 cents, they would be in a fool's paradise. They would be losing part of their capital; burdening themselves with the conduct of a vast business for less real return than they could get for their money by buying gilt-edged bonds and doing nothing.

But we must remember that the period we have reviewed is the first eighteen months of the mine's history. It is entirely likely that the mine will be worked out with an annual production averaging 75,000,000 lb. The managers believe that operating costs will be under 8 cents, which will change to 8.5 on the basis I have used. Let us agree to that and add an annual depreciation charge of $300,000. Let us say further that the capital employed will rise to a net total of $8,000,000. We shall have then the following costs:

Operating	8.5 cents
Depreciation	0.4 cents
Amortization	0.8 cents
Total cost	9.7 cents

This means that 8.9 cents is the dividend cost and 9.7 cents is the metal selling cost.

Owing to the great prospective importance of the type of mine that it represents, and also because it is an example of a good report to stockholders, I have thought best to reproduce here almost the whole report of the Utah Copper Company for the period of eighteen months ending with the year 1908. This report shows better than any other statement I have seen, matters that occupy the attention of the management, the equipment, and plants required, and the conduct, in general, of such an enterprise.

The problem involved is to take a disseminated ore containing 2 per cent. copper in the form of chalcocite from a very large deposit, concentrate it with a saving of 70[1] per cent. into one ton for every twenty-two

[1] These figures are not being realized. The actual yield of refined copper does not seem to be over 20 lb. per ton. This fact may invalidate my conclusions as to the cost of copper from this type of deposit. See Chapter XIII.

tons mined, the concentrate running over 30 per cent. in copper. The company does not smelt its own ores, but has it done by contract by the Garfield plant of the American Smelter Securities Company.

The following report is by the general manager, Mr. D. C. Jackling:

Utah Copper Company
December 31, 1908
Income Account

54,051,212 lb. copper at 13.36 cents	$7,222,406.85	
Debit difference in copper settlement for the period, 0.16 cents	87,639.06	
Net price applying for the year's sales, 13.20 cents	$7,134,767.79	
20,072.18 oz. gold at $20.00 per oz	401,443.60	
163,952.87 oz. silver at 54.76 cents	89,780.33	
Shipments of ore other than concentrating	37,877.38	
Rents received	9,300.90	
Interest, freight, refunds, sale of power, etc	9,399.36	
		$7,682,569.36
Operation	$2,666,284.44	
Mine development	20,027.80	
Prepaid expense—ore stripping	121,103.20	
Freight on ore	658,754.14	
Treatment and refining	1,806,658.52	
State of New Jersey, Annual License Tax	4,005.90	
Extraordinary tailings expense, Bingham Canyon	3,581.98	
		$5,280,415.98
Net profits for period		$2,402,153.38
Interest on bonds	$40,755.00	
Dividends paid	696,387.50	
		737,142.50
Net surplus for 18 months ended December 31, 1908		$1,665,010.88

Utah Copper Company
RECEIPTS AND DISBURSEMENTS
July 1, 1907, to December 31, 1908
Receipts

Balance on hand July 1, 1907	$35,802.68
[1] Issuance of 214,150 shares at $10.00 per share	2,141,500.00
[1] Premium on sale of 214,150 shares at $10.00 per share	2,141,500.00
Received from sale of bonds	1,500,000.00
Accounts payable	308,452.40
United Metals Selling Co	991,899.06
Net surplus for period	1,665,010.88
	$8,784,165.02

A portion of Mr. Jackling's remarks are now omitted and for them are substituted some extracts from the statements of Mr. R. C. Gemmel in the company's report for 1918.

[1] These items cover conversion of $4,283,000.00 par value bonds converted into stock at $20.00 per share.

References to the map of the company's mining property appended to this report will show the additional area of fully and partially developed ore resulting from the underground work during the period. In the report for the year ending June 30, 1907, the statement was made that the developed and partially developed area amounting to seventy-two acres. Developments since then have resulted in extending this area about eight acres, so that now the known ore area, fully and partially developed, is approximately eight acres. The ore thicknesses and values of this additional territory are, generally speaking, similar to those described in the former report, so that the new developments have resulted in additional ore reserves to the extent of about 8,000,000 tons, or at a rate during the period of over three times the rate at which ores were extracted for reduction. The net result of the developments we have made during the period has been that fully developed ore remains approximately as stated in our last annual report, viz., 20,000,000 tons, as the area of this class of ore has been increased to an extent that will more than offset the quantity of ore mined.

The two classes of partially developed ore, described in the former report, have been increased in the aggregate to the extent of approximately 8,000,000 tons, as above stated, so that we now estimate 60,000,000 tons in these two classes of reserves. In other words, of fully developed, partially developed and reasonably assured ore, the total amounts to about 80,000,000 tons. Of this total tonnage, 65,000,000 tons can be classed as of the better or normal grade, averaging about 2 per cent. copper, and 15,000,000 tons as of the lower grade, approximating 1½ per cent. copper. In addition to this, we have the lower zone, as described in the previous annual report, the average value of which has been indicated to only a limited extent by diamond drilling, but which is estimated contain a minimum of 40,000,000 tons that will probably average 1½ per cent. In discussing the above quantities throughout, consideration should be given to the fact that the stated figure include the quantities of ore mined during the fiscal period. This would amount, in percentage, to approximately 3 per cent. of the above described three classes of ore aggregating 80,000,000 tons reserves.

All the development done during the period has been on the easterly end of the property and on both sides of the canyon, but the larger part of it has been on the south side of the canyon, in the southeasterly portion of the company's territory. The ore-bearing area is still being extended in that direction.

Stripping.—Stripping operations since their commencement, in August, 1906, have resulted in the removal of 1,705,322 cu. yd. of capping. Of this amount, 1,335,233 yd. have been removed during the fiscal period under discussion. During the first six months of the fiscal period, 367,950 cu. yd. were removed; during the second six months, 446,460 cu. yd. were removed, and during the last six months of 1908, 520,823 cu. yd. were removed.

The total area over which stripping operations have been conducted to date is 19.7 acres. The average thickness of capping, as disclosed by these operations remains the same as that stated in our last annual report approximately 70 ft., corresponding to 113,000 cu. yd. per acre. The total amount removed is, there fore, equivalent to stripping of approximately 15 acres, and, at the present time, the actual area completely stripped is slightly in excess of 7 acres.

The average cost of stripping, throughout the entire operations from their beginning in 1906, has been approximately 32 cents. per cubic yard; this cost covering only the removal of capping and its conveyance to available dumping

ground. Applying this cost to the average thickness of stripping removed and ore uncovered, the cost per ton of ore uncovered is somewhat less than 4 cents. Stripping operations have been more expensive and difficult in the past than they will be in the future, on account of the very limited area upon which the shovels could work and the expensive tracks it was necessary to build in starting these operations in the narrow canyon. As we develop more room, the rate at which shovels can operate will be increased, and the cost of shoveling correspondingly reduced; but the expected decrease in the actual cost of loading the material will probably be offset by the increased cost of outing the waste material for greater distance, so that it may be expected that our stripping costs will remain about the same as in the past."

Report of 1918

Ore Reserves.—At the end of the year 1918, an ore area of 226.3 acres had been outlined by underground workings and churn drilling. No attempt was made to add to this area, but some drilling was done in order to obtain data for future steam shovel operations. The churn drilling, however, increased the calculated average thickness of developed and partially developed ore from 508 feet to 556 feet.

Revised calculations show that at the end of the year there was developed in the property 453,421,400 tons of ore, averaging 1,375 per cent. copper, of which quantity 270,000,000 tons are classed as fully developed and 183,421,400 tons as partially developed. There was mined from the entire property prior to January 1,1919, a total of 79,308,140 tons of ore, averaging 1.397 per cent. copper, and the reserves, therefore, amount to 374,040,000 tons averaging 1.370 per cent. copper. The year's addition to reserves was 2,288,000 tons in excess of the tonnage mined during that period.

The net value of the gold and silver recovered was 0.795 cent per pound, and the miscellaneous income in Utah, including that from the Bingham & Garfield Railway, amounted to 1.003 cents per pound. The operating costs on concentrating ore, including all fixed, general and maintenance charges for the years 1910 to 1918, inclusive, are shown in table below:

Year	Tonnages	Mining	Transportation	Milling	Total
1910	4,340,245	$0.4097	$0.2978	$0.4663	$1.1738
1911	4,680,801	0.4479	0.3078	0.4168	1.1725
1912	5,315,321	0.4233	0.2848	0.4158	1.1239
1913	7,519,392	0.3288	0.2797	0.3676	0.9761
1914	6,470,166	0.3232	0.2782	0.3536	0.9550
1915	8,494,300	0.2441	0.2781	0.3402	0.8624
1916	10,994,000	0.2781	0.2792	0.3782	0.9355
1917	12,542,000	0.4446	0.2794	0.6930	1.4170
1918	12,160,700	0.5370	0.2983	0.9277	1.7630

STATEMENT OF OPERATIONS
For the Year Ended December 31, 1918

Operating Revenue:		
Copper Produced—188,092,405 lb. @ 22.876c....	$43,029,021.49	
Gold Produced— 50,928,217 oz. @ $20.........	1,018,564.34	
Silver Produced—489,483.74 oz. @ 97.561c......	477,543.66	$44,525,129.49
Operating Expenses:		
Mining and Milling (including Taxes)..........	$17,076,992.59	
Treatment, Refining and Freight...............	12,066,465.78	
Selling Commission...........................	303,918.71	
Stripping Ore................................	1,235,057.50	
Mine Development..........................	35,392.26	$30,717,826.84
Net Income from Operations plus Depletion.....		$13,807,302.65
Miscellaneous Income and Receipts:		
Dividends on Investment....................	$ 1,600,300.00	
Capital Distribution—Nevada Consolidated.....	2,651,325.00	
Other Income from Interest, Rentals, etc........	886,852.31	$5,138,477.31
Total from all Sources.......................		$18,945,779.96
Other Charges:		
For Contributions to Red Cross and United War Work Funds..............................		500,000.00
Balance to Surplus Account..................		$18,445,779.96

SURPLUS FROM OPERATIONS

Balance—December 31, 1917..................		$48,293,528.23
Net Income and Proceeds of Depletion.........		18,445,779.96
		$66,739,308.19
Less:		
Dividends..................................	$12,589,797.50	
Capital Distribution........................	3,655,102.50	$16,244,900.00
Balance—December 31, 1918.................		$50,494,408.19

CONSOLIDATED STATEMENT OF ASSETS AND LIABILITIES

ASSETS	December 31, 1918		December 31, 1917		Increase
Mining and Milling Properties and Equipment................	$27,835,991.61		$24,172,445.85		
Railway Properties and Equipment..........	8,323,984.33		7,849,012.35		
	$36,159,975.94		$32,021,458.20		
Less—Reserve for Depreciation.......	4,542,125.08		3,385,758.53		
		$31,617,850.86		$28,635,699.67	$2,982,151.19
Investments..........		5,609,425.22		5,604,002.23	5,422.99
Patents and Process Rights..............		312,694.00		300,000.00	12,694.00
Deferred Charges to Operations...........		8,943,523.85		8,300,040.34	643,483.51

					Increase
Current Assets:					
Cash................	$ 8,771,328.78		$11,533,737,92		
Cash due in January for December Copper Deliveries..........	3,695,141.86		3,962,156.56		
Marketable Securities	12,458,312.82		4,869,283.00		
Accounts Receivable, Prepaid Insurance, etc.................	833,715.68		395,825.55		
Notes Receivable.....	....		10,800.00		
Metals on Hand and in Transit..........	8,709,791.16		13,166,994.92		
Materials and Supplies...............	4,549,755.44		5,084,139.12		
		39,018,045.75		39,022,937.07	4,891.32*
		$85,501,539.68		$81,862,679.31	$3,638,860.37
LIABILITIES					
Capital Stock Outstanding (Utah Copper Company).......		$16,244,900.00		$16,244,900.00	
Current Liabilities:					
Accounts Payable....	$ 1,105,077.03		$ 1,523,244.84		
Accrued Treatment, Refining and Delivery Charges.............	2,390,112.53		1,930,009.77		
Reserve for Taxes, Accident Insurance, etc................	6,620,785.46		5,327,475.06		
		10,115,975.02		8,780,729.67	$1,335,245.35
Surplus from Sale of Securities..............	$ 8,290,620.00		$ 8,290,620.00		
Surplus from Operations................	50,840,044.66		48,546,429.64		
		59,140,664.66		56,837,049.64	2,303,615.02
		$85,501,539.68		$81,862,679.31	$3,638,860.37

*Decrease.

Bingham & Garfields Railway Company

Construction and Improvements.—The total increase in length of all tracks was 14.18 miles. A large part of the additional mileage was for the track layout in connection with the new car dumper at Arthur. The mileage at the end of the year 1918 is shown in table below:

Main Line and branches between and in the vicinity of Garfield and Bingham..	37.136 miles
Yard and Siding Tracks, including all the terminals...............	52.769 miles
Additional tracks leased to Utah Copper Company................	43.458 miles
Total length of tracks..	133.363 miles

Other improvements include a new scale house, new office building for superintendent at Magna, extensions to the engine house and back shop, and some additional necessary tools and machines for the shops. One Mallet articulated compound locomotive and four outfit cars were added to the equipment.

20

Operations.—A total of 12,439,394 tons of freight was transported, being an average of 34,081 tons daily, compared with 12,648,225 tons and 34,653 tons, respectively, for the year 1917. A total of 10,949,278 tons of ore was shipped by the Utah Copper Company; 368,473 tons by other mining companies in Bingham, and 26,484 tons by mining companies in Nevada through the Western Pacific connection, making a total of 11,344,235 tons of ore. The remaining 1,095,159 tons was commercial freight, as compared with 1,069,894 tons of such freight transported during the previous year. A twice-daily passenger train was operated between Salt Lake City and Bingham in connection at Garfield with the Los Angeles & Salt Lake Railroad. The total number of passengers carried was 617,749, as against 671,004 for 1917.

Inspiration Consolidated Copper Company.—If the Utah Copper is the most conspicuous open pit mine of the porphyry group, Inspiration is certainly the most interesting underground mine. To illustrate this I find it difficult to choose between the singularly terse and energetic reports of Mr. C. E. Mills who was general manager during the formative period. I select that for 1916 with one or two remarks in that of 1915—I quote the latter first.

Three years prior to the starting of production at Inspiration roughly 100,000,000 tons of ore, seventy-five million of which was sulphide, had been developed by churn drilling. A comparatively negligible amount of underground work was done. To prepare and equip the property for the mining and concentration of 5,000,000 tons of sulphide ore per annum—roughly 14,400 tons daily capacity—an expenditure as follows may be set down:

	Cost per ton of daily capacity
Equipment of mine and mill, including water supply, power, mill sites, tailings lands, railroads, etc.	$625
Advanced mining expenditures to prepare for an output of 14,400 tons per day	208
	$833

The advanced payments for mining will appear at the proper time in the mining costs.

A considerable part of the plant equipment expenditures will last the life of the mine. Improved metallurgy will doubtless justify replacements of other parts. The oxide ores will probably call for a treatment method of their own.

The operating costs at Inspiration for mining and milling will probably be from $1.00 to $1.15 per ton of ore, possibly nearer the former figure. While a yield of more than 20 lbs. per ton of ore can be obtained from much of the ore, a better mining practice can be followed and more ultimate profits obtained by mining ore producing 20 lb. on the average.

I herewith submit a report of operations at the Company's mines for the year 1916—the fifth annual report since the organization of your company and its acquisition of the Live Oak and Inspiration Mines in March, 1912, and the first report covering a full year's activities in the production of copper.

A very brief review of the time intervening between March, 1912, and the close of the past year may be of interest. The character of the work under way suggests three divisions of the total interval.

First Period.—March, 1912, to June 29, 1915 (when the first unit of the mill started). This was a period of plant construction and underground development.

At the beginning of this period the mines had already been developed by churn drills but only very slightly by underground work.

The second quarter of 1912 was occupied in the selection of a mill site, its purchase together with suitable lands for tailings storage and with negotiations for hydroelectric power.

In July, 1912, active underground work was started.

On August 2, 1912, the first grading contract (for the railroad) was let.

On November 3, 1912, the first grading actually began on the mill site.

On January 1, 1913, Flotation tests began in ten ton plant and continued for six months. In following six months a 700 ton (daily capacity) flotation test mill was built.

On January 1, 1914—700 ton flotation test plant started—ran until June 29, 1915, treating 257,000 tons ore.

On July 30, 1913, the first concrete was poured for surface structures.

Twenty-three months later the first unit of the mill was started.

Seven and two-thirds months following this, the last or eighteenth unit of the mill was started.

Meanwhile, the main shafts were sunk and equipped, the power house, railroad, etc., built, and the water supply developed and equipped.

53.7 miles of underground openings were driven to operate the mine.

6,858,000 tons of ore were developed by churn drilling in the Live Oak.

7,500,000 tons of ore were acquired by purchase of Keystone group of claims.

Second Period.—July 1, 1915, to December 31, 1915—Covering construction work on unfinished units of the mill and operation of mine in connection with the finished units of the mill. Production of copper during this period 20,445,670 pounds.

Third Period.—The full operating year of 1916.

In 1916, mining operations of the Company were substantially confined to the Inspiration Division. The Keystone property was not worked at all and the Live Oak and Cordova group only to a very limited extent in supplying with silicious oxidized ore the small market furnished by the International Smelter for this class of material. The concentrator was fully supplied from the stopes of the Inspiration Division.

In all 5,353,880 tons of ore were mined during the year, 21,289 tons being the maximum for any single day.

The average output of ore per shift's work chargeable to the Mining Department was 17.46 tons.

The area covered by the undercutting of ore was 18.4 acres.

28 miles of underground openings were driven and 31 miles of such work were destroyed in the caving operations.

Details are as follows:

TONS ORE MINED

*Milling ore..............................	5,332,058	From Inspiration Division

* Includes 200,859 tons reclaimed from dumps by driving branch raises from the mine below, and drawing ore down to the mine haulage ways.

Silicious ore sent to Smelter..................	1,969	From Inspiration Division
Smelting ore direct to Smelter..............	18	From Black Copper Claim
Oxide ore direct to Smelter.................	9,473	From Live Oak Division
Oxide ore direct to Smelter.................	10,362	From Cordova Group
Total...............................	5,353,880	

DEVELOPMENT WORK UNDERGROUND

	Openings driven to beginning of 1916, miles	Driven during 1916, miles	Total driven to end 1916, miles	Destroyed by stoping operations to end 1916, miles	Mine openings end 1916, miles
HaulageWays............	7.61	0.98	8.59	0.26	8.33
Ordinary sized drifts.......	22.69	7.09	29.78	11.79	17.99
Main Raises..............	23.20	7.45	30.65	5.69	24.96
Finger Raises.............	8.93	12.55	21.48	13.25	8.23
Shafts...................	1.21	.....	1.12	0.17	1.04
Misc....................	0.21	.....	0.21	.....	0.21
	63.85	28.07	91.92	31.16	60.76

The refined copper returnable by the Smelter as the result of all ore treated in 1916 was:

	Pounds copper
From concentrating ores............................	119,431,389
From oxide ores sent direct to Smelter.................	1,341,248
	120,772,637

The cost of copper derived from concentrating ores was:

	Cost per pound	Cost per ton ore
Mining....................................	2.702c	$0.60708
Coarse crushing............................	0.125	0.02798
Ore hauling................................	0.069	0.01540
Concentrating and royalty....................	2.243	0.50385
Concentrate hauling.........................	0.006	0.00145
	5.145	1.15576
Smelting, freight, refining, marketing, etc., etc....	3.528	0.79269
	8.673	1.94845
	119,431,389 lbs.	5,316,350 tons

It is estimated that for each 1000 tons of ore mined there will have to be driven (including the original preparatory work) 13 feet of ordinary sized drifts, 20 feet of main raises and 1.4 feet of haulage ways, making a charge for this account of approximately 20 cents per ton of ore mined.

In the 1916 cost of mining as it appears in the above cost tabulation:

	Per ton ore
For driving of drifts, main raises and haulage ways, there is charged........	$0.20
For undercutting and caving, drawing, loading, hauling, hoisting, etc., together with a proper proportion of all general charges, the cost was.......	0.406
	$0.606

However, the actual cost during the period for driving drifts, main raises and ways, amounted to 10 cents per ton. That is to say, the actual cash expenditure per ton for mining in 1916 was $0.506.

The copper in the ore occurs mainly in combination with sulphur, but partially in oxide combinations. The first is readily separated from the waste rock in which it occurs by either flotation or gravity concentration. The oxides, however, give but poor recoveries by either means. The ore milled in 1916 ran 1.548 per cent. Cu and the recoveries were as follows:

	Assay of ore	Percentage saved in milling
Copper in sulphide form..................	1.213	90.95
Copper in oxide combinations..........................	0.335	16.60
Total copper in ore................................	1.548	74.86

As against the mill record for the latter half of 1915, the above record shows some improvement in the recovery of sulphide copper, but a lower total recovery due to an increased proportion of oxide copper in the ore.

The last six sections of the present mill were not quite completed at the beginning of 1916, but went into commission as follows:

Section No. 13 on January 6th, 1916
Section No. 14 on January 9th
Section No. 15 on January 21st
Section No. 16 on January 24th
Section No. 17 on February 1st
Section No. 18 on February 21st

Due to this and the further fact that the grinding capacity of the mills gradually increased throughout the year, the two half year's work compare as follows:

The average daily tonnage milled during the first half year was.......	13,466 tons
The average daily tonnage milled during the second half year was.....	16,203 tons
The average daily tonnage milled during the past month, February, 1917, was..	17,013 tons
The production of copper for the first half year of 1916 was........	53,962,136 lbs.
The production of copper for the second half year of 1916 was.....	66,810,501 lbs.
	120,772,637 lbs.

During the year two additional sections of the mill have been under construction and should start within the next two months, adding about 11 per cent. to the present capacity.

Attached here to, you will find details of the concentrating operations for the year.

Respectfully,

C. E. Mills,
General Manager.

Inspiration Consolidated Copper Company

Mill Statistics—Year 1916

Dry tons milled		5,316,350.1
Tons per day		14,850.1
Average number of sections running		16.54
Average tonnage rate per section		897.8
Assay mill feed—per cent. copper		1.548
Screen analysis of feed (on 48 mesh)		3.3
Per cent. copper in feed—oxidized		0.335
Assay of general tailings—per cent. copper		0.397
Per cent. copper in general tailings—oxidized		0.283
Per cent. copper in general concentrates—smelter assay		30.688
Per cent. copper in flotation concentrates		37.50
Per cent. copper in table concentrates		11.23
Per cent. moisture in general concentrates		17.27
Tons concentrates produced per ton of ore		0.377
Recovery of copper calculated from: (Smelter Assays)		
Assays only		75.33
Assays and weights of concentrates and feed		74.86
Assays and weights of concentrates and tails		75.18
Assays and weights of feed and tails		75.29
Recovery of copper sulphides		90.95
Water used per ton ore—total gallon (February, 1917, figures)		1108.0
Water used per ton ore—		
Reclaimed in tanks at foot of Mill	354	
Reclaimed from ponds	528	
New water from Kiser Pump Station	226	
Steel ball consumption per ton of ore milled		1.76
Flotation oil consumption per ton of ore milled (pounds)		1.287
Coal tar	1.20	
Other oils	0.087	

CHAPTER XVII

THE NORTHWESTERN COPPER FIELD

Climate and geography of the north western coast—Inlets and glaciation—Economic advantages—Probability of further mining developments—Butte—Its comparison with the porphyry mines—Anaconda costs in 1915—Butte in 1908—Granby consolidated in 1908—Hidden Creek.

In the region along the northwestern border of North America, extending from Butte, Montana to south-central Alaska, there is made at present an annual output of copper of about 500,000,000 pounds, or more than twice that of the Lake Superior region. In this territory by far the most productive district is that of Butte, which is now fully developed and is not likely to add further to its production. At the other extremity of the field the Kennecott Copper mine, which has been an extraordinary bonanza, seems also to have reached or passed its zenith. But in so large a tract it is reasonable to expect that the output mentioned will be maintained or increased.

In climate and appearance this region is in marked contrast to the southwestern copper fields. The one marked feature is the presence of a coast range or ranges along the border of the Pacific. The central portion of these ranges has within recent geological times been depressed so that the mountains, valleys and canyons are now partially flooded by the sea. This is the case all the way from Puget Sound as far north as Skagway, Alaska, a distance of nearly 1000 miles. Thus the whole coast has been made exceedingly picturesque. While the scenery of this region, of course, is generally known, the actual facts concerning it are not perhaps fully realized. For instance at the Portland canal, which forms for some distance the boundary between southeast Alaska and British Columbia, the canyon, which is flooded by the ocean, has the scale of the Grand Canyon of Arizona. Within three miles of the shores of this narrow inlet glacier-covered mountains rise to heights of over 5000 feet. The water, which is not more than two or three miles wide, is over 1000 feet deep, so that the scenery while very different from that of the Grand Canyon is at least as imposing. In many other places equally striking scenes may be found. But while the coast ranges are partially flooded they are everywhere high enough to catch a great deal of the moisture of the Pacific, so that inland at distances not more than 50 to 100 miles from the coast there is a semi-arid belt which extends continuously downward through the plateau regions well into Mexico. Butte is in this semi-arid belt. There are places in British Columbia where the rainfall

is only 8 to 10 inches a year. But the effect of this slight precipitation is very different from that found farther south. In the winter the proportion of cloudy weather is very much greater and all the hillsides are covered with growths of pine and other evergreens. It is only the level plains that remain unforested. While the winters cannot be said to be very severe as compared with those of the northeast part of the country there is still a good deal of snow and many weeks of sharp frost.

To return to the coast ranges, we may say that they are the most conspicuous feature of the geography of the region, for their presence gives rise to the semi-ardidity of the continental belt just east of them, and they also present in themselves interesting climatic, geographical and geological features. The mountain summits of the coast ranges are frequently islands or peninsulas. The Olympic mountains west of Puget Sound are about 9000 feet high and covered with glaciers. The northern extremity of the Cascade mountains just east of Puget sound is a ridge about 6,000 feet above the sea, but on its summit are a number of lofty volcanoes, such as Mt. Helens, Mt. Adams, Mt. Rainier and Mt. Baker, rising to heights of from 10,500 to 14,500 ft., all covered with snow and ice. This range seems to come to an end just north of the international boundary line, south of the Frazier River; but only a few miles toward the northwest the coast range of British Columbia begins and even within a few miles of Vancouver it shows an altitude of 4000 feet or more and still farther northwest reaches heights of 11,000 to 12,000 feet. At such heights, of course, it is universally covered with snow and has been glaciated for long periods so that in some places the range consists of a series of spiral shaped peaks like the Matterhorn, rising through the snow fields. At one place I have counted over thirty of such peaks. Vancouver Island is separated from the Olympic peninsula by a narrow strait. It consists of a mountain ridge some 350 miles long with more or less gentle slopes toward the north east. The continuation of this chain toward the northwest, or at least similar groups of mountains, form the numerous large islands of the coast of British Columbia and southeast Alaska.

There are abrupt changes in the rainfall on the different sides of these islands or mountains. The westward or windward side is exceedingly rainy, in some places rising to 140 inches. On the eastward side it may be only 20 or 30 inches. Thus on Vancouver Island the City of Victoria at the southeast extremity has an average rainfall of only 31 inches, and Seattle on Puget Sound only 37 inches, but during the winter there is a great deal of cloudy weather in both places. Instead of heavy rains there are long continued drizzles which give the visitor the impression of much rain, although as a matter of fact the precipitation of either of these places mentioned is a good deal less than that of New York or Boston.

But the rainfall for a considerable distance from the coast is heavy enough to produce a heavy forest growth. The Douglas Fir, otherwise known as the Oregon Pine, forms an immense forest on Vancouver Island but farther northward this tree no longer appears, its place being taken by heavy growths of cedar and spruce. The long periods of damp cloudy weather seem to be favorable to numerous fernlike plants such as one finds in the rainy regions of the tropics.

The coast ranges seem to have been uplifted slowly across the courses of rivers which take their rise in the interior. These streams were able during the uplift of the mountains to continue to cut their way through, thus producing the canyons referred to, which have become inlets that extend back in many cases more than 100 miles. During the glacial period the whole country was covered with ice and each of the inlets was occupied by such portions of the general glacier that flowed faster than the rest so that at present their walls are thoroughly smoothed and polished.

The visitor from other regions is astonished to see the swamp growth climbing up the sides of some of these steep mountains. In some places formations of peat are found actually on crags difficult to climb. Of course in most regions a peat swamp is only found in a dead level.

It is hardly necessary to say that the invasion of the sea among the coast ranges is an important economic feature. The coast is a succession of deep harbors some of which actually traverse the mountains to the comparative level country further inland. The abundance of timber and the cheap water transportation are important to the mining business, or any other business for that matter. A number of considerable cities have already grown up on these inlets, supported by trade that extends to all parts of the world. Of these the most southerly is Portland on the Columbia river, the most southerly of many rivers that cut through ranges. On Puget sound and its northerly continuation the strait of Georgia, are the large towns of Tacoma, Seattle Victoria and Vancouver. Still farther north is Prince Rupert where the Canadian Grand Trunk Pacific has built its terminal after passing through the mountains along the Skeena river.

In various portions of this territory or contiguous to it there are numerous coal fields, the largest of which is in southeast British Columbia facing the great plains. In this region is the Crow's Nest Pass coal district, which produces an excellent coking coal; but coke is also made in a rather small field of Cretaceous age on Vancouver Island. A great deal of coal, mostly of rather inferior quality also occurs in Montana. An extensive coal field of Tertiary age occurs in the basin of Puget Sound. In Alaska there are also coal fields which have been much advertised in the newspapers chiefly as subjects of controversy, but which are not at present of great commercial importance. I recite these facts as a basis

for the expectation that the industries of this region will be found capable of great development. Along a great part of the coast region it is no exaggeration to say that the factors making for cheap mining are altogether exceptional. This is an argument for supposing that it will be found possible to work ore deposits that might, in less favored places, prove unpayable.

The geological features of the coast ranges are such as to give rise to the expectation of finding considerable and persistent mineralization. An immense granite batholith of moderate geological age forms the core of the mountains and around the edges of this many deposits of sulphide ore have been found. In the coast range proper only two of these have been developed as yet into important copper mines, namely the Hidden Creek property at Anyox, British Columbia, and the Britannia mine near Vancouver, but many others are known, such as the gold of Douglas Island, Alaska, a copper district on the White Horse river and many similar mines and prospects. Two features which should be specified that bear on the possibility of other mines being opened up: first the heavy forest growths and the boggy nature of the soil effectively conceal the rocks over large tracts, and second, the heavy glaciation has swept off such portions of the orebodies as may previously have been oxidized with the accompanying secondary enrichment, so that the miner is compelled to face at once the problem of working the unaltered sulphides. To start successfully under these conditions is usually a matter requiring considerable capital. It is, therefore, no poor man's mining country. But I have a strong impression that the development of the flotation process and the use of considerable capital will make commercially available ore that will average only 1 or 2 per cent. copper and of such a considerable amount apparently may be found.

To one accustomed to living in Butte, Montana, these general descriptions of the coast ranges and the geography of the northwest may seem rather a far cry, for that locality shows only a meager resemblance to the coast country itself. However, quite close to Butte, in the Cœur d'Alene mountains, the features of the country are not far from those I have just described. Butte itself is in most respects more similar to the general plateau regions of the Rocky mountain system. It is surrounded by grassy plains broken by numerous hills and mountain ridges forested with pines. It is, however, separated from other copper producing districts to the southward by a gap of many hundred miles and its ore deposits belong to the mountain-building period which occurred at the close of Mesozoic times. The Butte batholith is merely a portion of a series of great intrusions that are found here and there over a large area of Montana and Idaho cutting through sediments of upper Cretaceous age. I have no reason to assert that the coast ranges of British Columbia are of the same age, but it is not improbable. I am sure they cut through

rocks at least as young as the lower Cretaceous. Thus in a general way it seems as if the principal deposits of Montana, Idaho and British Columbia do belong to the same geological province.

The Butte, or Boulder batholith is exposed over an area of over 2000 square miles. Around its border are minor mineral districts, but the principal one, Butte itself, is in the south central portion of it. This great intrusion has been abundantly described not only by the United States Geological Survey, but by many private writers, particularly H. V. Winchell, Reno H. Sales and other geologists employed by the Anaconda Copper Company. It appears that the mineralization took place in the hardened crust of the batholith, probably before the deeper seated portion had become thoroughly solidified. Some quartz porphyry dikes within the district are thought to be the upward prongs of a renewed intrusion within the body of the main one. However this may be, it is certain that the orebodies were formed before the mass had reached the stage of quiescence because the mineralized waters followed at different periods fissures that were formed after a portion of the mineralization had been accomplished. Thus the veins cross and fault each other in a most intricate way, the details of which have never been fully published. The area of the Butte district is small, covering perhaps 1500 acres. From it have been obtained some 3,500,000 tons of metallic copper and the end is not by any means in sight. It is interesting to compare for a moment the volume of such copper with that obtained from that of some of the disseminated deposits further south. The area covered by the Utah Copper Mine is only a little over 200 hundred acres, yet it is known to contain as much as has been produced by the entire Butte district. A similar comparison might be made with almost any other of the other large porphyry deposits. Thus it appears that even with respect to superficial area the mineralization of Butte is not so concentrated as that of the porphyry districts; but when we consider in addition that the ores are spread over a vertical range of more than 3000 feet as compared with only a few hundred feet in the case of the porphyries the comparative sparseness of the minerals becomes much more evident still. If we may suppose that Butte is worked out to an average depth of 2000 feet over an area of 1500 acres we find that its product of copper is only about 6 tenths of a pound of copper per ton of rock in the inclosed volume, as against a yield of 15 to 30 pounds per ton in the case of the porphyry mines. It seems as if nothing could show more clearly the difference in the problem of mining.

A territory so poor by comparison en massè is made commercially valuable only by the concentration of the copper in veins or limited areas. Since not all of the rock can be taken out, it follows that the richer portions, which after all are only a minute portion of the whole, say 1 per cent., must be searched for by means of expensive underground de-

velopment work. A person does not have to be an expert in mining to recognize such a difference. In dollars and cents it is represented by the cost for mining which is \$1 per ton, and in some places a good deal less, among the porphyry mines of the south, as against about \$3.50 in the Butte district under pre-war conditions, and something like \$6 per ton in 1918.

It has been thought that there must be something wrong with the mining practice of the Butte district to make the cost of mining so high. The answer to this is that many able engineers and managers have tried to reduce it but have universally failed. Some twenty years ago, in the late 90's, when the wages were lower and general operative conditions much better than they have been since, a portion of the mines of Butte, namely those of the Boston and Montana Company were able to mine their ores for about \$2.65 a ton, but this was not maintained, and I suppose no mine in the district has, of late years, even before the war, been able to cover all its expenses at less than \$3 per ton.

The expectation that cheaper work could be done arose in all probability from a misconception of the facts. There is always in such a district as Butte some large deposits that are described first, conveying an impression that they represent the ore bodies as a whole. I remember nearly thirty years ago of reading in newspapers a description of the Anaconda vein at Butte, which said that the ore was more than 20 square sets wide, more than 120 feet, and very rich, etc, etc. Now unquestionably such stopes existed, very likely they are to be found today, but so far from representing the whole bodies of the district they do not even represent a single vein. Such places are merely swells or local enrichments. The fact is that most of the ore comes from rather narrow streaks frequently occurring between walls of soft, partially decomposed granite. The enrichments or ore-shoots frequently come to an abrupt end, either upward on account of the leaching from the surface, or in any direction from original limitations of the mineralizations, very frequently by faulting. Not only the orebodies but actually the largest veins progressively change their appearance and even their structure from level to level. These changes are not revolutionary or very great in a distance of a hundred feet, but in a vertical range of one or two thousand feet the changes are so great that one acquainted with the orebodies at the top if shown those at the bottom without tracing them through would find nothing to induce him to believe that they were related in any way.

In short, the cost of mining in Butte is necessarily so high it must be looked at as the principal factor which will limit the production of that district.

The Anaconda Copper Mining Co.

This introduction will serve to explain many features in the history of the Anaconda Co. which has now become, not only a mining concern,

but an important financial organization doing a general business in mining smelting, refining, marketing and manufacturing; its products include not only copper, but also lead, zinc, silver, gold and other metals. In the ten years since the first edition of this book was published, changes in this direction, by consolidation, purchase and expansion have been going on practically all the time, until it is scarcely an exaggeration to say this concern does practically all of the copper mining at Butte. It is scarcely worth while to specify the dates at which all the changes have taken place, but roughly, the Anaconda which was long the principal copper mine of the district but which had at later times many important rivals, has been made to absorb nearly all the others and finally the holding company to which it itself belonged—the Amalgamated Copper Co. During the past ten years the Butte Coalition Mining Company, the copper mines formerly owned by Senator W. A. Clark, the Parrott Mine, the Boston and Montana and the Butte and Boston have all been consolidated, principally, by interchange of stock. The International Smelting Company and The United Metals Selling Company, which owned a lively refining business on the Atlantic Coast have also been merged. A considerable interest has been obtained in the Inspiration Copper Company of Arizona. Many isolated claims have been purchased and large properties bought for development in South America. Great investments have been made in improving smelting plants in Montana and development of a process and plant for the production of electrolytic zinc.

A careful study of the annual reports makes it plain that these changes were more or less necessary to prolong the life and maintain the earning power of the Company. In other pages it is shown that for many years it has been a struggle to maintain an output of ores of high enough grade to permit the extraction of copper at a reasonable cost. It was stated in the first edition that if the increase of costs, which had been showing itself for a number of years in the mines of the old Anaconda Company, were to continue for another ten years that those properties would no longer be profitable. The ten years have passed, but the prediction has not come true, the reason being that the efforts of the management have prevented it. One may discern these efforts in every direction; in the improvements in the mines by way of better ventilation, the concentration of pumping and hoisting operations to as few points as possible, and the reduction of power costs. In the smelting works there have been similar changes, designed principally to increase the extraction of copper from the ores and also to reduce the cost of transportation, and, very likely, of operating also. For many years the Company operated two large plants, one at Anaconda, at a distance of only 26 miles and connected with the mines by a railroad owned by the Company, and the other at Great Falls, at a distance of 160 miles to which the ore had to be

transported over the Great Northern Railroad at a cost of $1.00 per ton. By the enlargement of the Anaconda plant it has been made possible to treat all the copper ores there and thus save the excessive transportation from Butte to Great Falls. Probably the principal agency for increasing the yield of copper has been the introduction of the flotation process of concentration.

By these efforts the yield of copper per ton has been maintained fairly well against the undoubted decline in the average value of the ores. Indeed, in the year 1917 and 1918 there was an increase in the yield of copper compared with 1915, of about 10 per cent., but is a reasonable supposition that a portion of this increase was due to war conditions. The company no doubt tried to keep up its output by mining its best ores. There was, as in other places, a considerable shortage and deterioration of labor. It is plain that the sole result of these efforts has been to *arrest* the decline in yield and the increase of cost. During the past few years the multiplicity of the activities of this concern have made it almost impossible to figure out the cost of individual operations. Mining and developments at Butte are confused with developments in South America; the smelting operations at Anaconda and Great Falls are confused in the statements with similar operations on zinc ores at Great Falls and with the various smelting operations of the International Smelting Company in Utah and Arizona. About the last year for which I can obtain a reasonably correct statement of the cost of operations at Butte was 1915. In that year the costs were as follows:

Mining	4,383,340 tons	$17,254,622 =	$3.93
Transportation	4,383,340 tons	1,029,670 =	.24
Reduction	4,805,694 tons	10,694,032 =	2.44
Freight, refining and selling		4,492,171 =	.94
Administration, taxes, etc.		573,545 =	.12
Total cost per ton			$7.67

Yield	Copper	55.2	Equal to about 66 lbs. Cu. Cost 11.8 cents per pound.
	Silver	1.9 oz.	
	Gold	50 cents	

If these costs were representative one is justified in stating that copper produced at Butte is hardly as cheap as the average. If under pre-war conditions it cost so close to 12 cents a pound under the present it can hardly fall under 18 cents.

Butte (in 1908).—The labor employed in the Butte mines is vigorous, intelligent, and, under normal conditions, abundant; but on the other hand, the wages are the highest paid in the United States, if not in the world, for any considerable volume of labor. Up to 1901 the average wages paid were 37 cents an hour. Since 1901 they have averaged 47 cents an hour, these figures being compared with 25 cents an hour for Lake Superior It is indeed probable that the Butte miners are better

and more effective than those of Lake Superior, but hardly to the extent required to make up this great difference. Under present conditions, wages in Butte are nearly 100 per cent. higher than in Lake Superior. It seems unreasonable to estimate that more than half of this difference can be made up by superior efficiency in Butte, so that in round numbers we shall have to estimate labor costs in Butte as at least 50 per cent. higher than in Lake Superior.

One unfavorable factor which may be classed as external is the location of claims under the apex law. This has meant the parceling out of the surface in small, irregular, and conflicting fragments, and this fact has interposed a serious obstacle to the comprehensive development and working of the mines. In this respect Butte does not perhaps suffer by comparison with other mining districts in the Rocky Mountain region; but as compared with Lake Superior this feature must be classed as a pronounced disadvantage.

Internal Factors.—The internal factors of the Butte mines are not unfavorable for fissure vein deposits, but they present certain characteristics which make for increased costs as compared with Lake Superior. The ores all come from an area of about two square miles, and from this area the output of copper and silver has been simply prodigious. This is a favorable feature.

The veins, according to H. V. Winchell, belong to three different systems. Of these the first and oldest, called the Anaconda system, strikes east and west and dips to the south. The filling of these veins is quartz and pyrites in which the original proportion of copper was probably small. These veins are intersected by mineralized fault fissures striking northeast and southwest, and both these systems are intersected and faulted by a third system of mineralized fissures running northwest and southeast. In addition to these veins, still later barren faults of considerable displacement intersect all the orebodies.

The result is a great complexity of vein structure which has proved a serious problem to unravel. As might be expected the various faults are accompanied by considerable zones of crushing and alteration which add materially to the difficulty of mining. An additional complexity is brought in by the influence of a pronounced reconcentration of values due to surface oxidation and leaching and subsequent deposition at greater depths. While it is true that in a great measure the orebodies owe their commercial value to this reconcentration, it is also true that it has resulted in an uneven distribution of the ore which imposes a necessity for sorting and is a factor of additional cost. The upper 200 or 300 ft. of the veins is absolutely barren.

The oxidation of the large bodies of pyrites and the decomposition of vast quantities of timber in these mines has resulted in the generation of an unpleasant degree of heat. The temperature must be kept down

by very thorough ventilation. Here we have a factor that makes for additional cost.

Method of Treatment.—The process of reduction in Butte is conducted about as follows: The ore is hoisted from the mine and dumped directly into large bins from which it is drawn into railroad cars and transported to combined concentrating and smelting plants. A small proportion goes to plants in the vicinity of Butte itself, and not more than two or three miles from the mines, but by far the greater portion is taken to Anaconda 26 miles away, or to Great Falls 100 miles away. At the smelter all ores containing less than 6 per cent. copper are concentrated. The higher-grade ores are smelted in blast furnaces and the concentrates in reverberatory furnaces collecting the metals into a matte which is bessemerized on the ground into blister copper. A portion of this blister copper is refined at the Great Falls plant, but by far the greater portion is shipped to the Atlantic seaboard in the neighborhood of New York and there refined. Nearly all the copper output of Butte is sold through the agency of the United Metals Selling Company.

The most pronounced factor making for high costs in the Butte ores is the large percentage that must be smelted. This can be estimated roughly at 40 per cent. as against 4 per cent. for the richest copper ores in Lake Superior.

The concentrating and smelting are largely done in two immense plants owned by the Amalgamated Copper Company, one at Anaconda, and the other at Great Falls. It is believed that these plants are equipped and operated as well as any in the world, no pains having been spared in capital expenditure to secure the greatest economy. But it is manifestly a physical impossibility to smelt 15 to 30 tons of ore at Butte for anything like the cost required to smelt one ton of concentrates in Lake Superior. Furthermore, the Butte copper must stand not only a very heavy transportation expense to the seaboard, but must further undergo the expensive process of electrolytic refining. The logical result of these conditions is that in Butte $4 a ton for concentrating, smelting, and refining may be considered as an absolute minimum as against a cost of from 60 cents to $1 in Lake Superior.

Mining in the Butte District.—It is not my intention to go into the details of mining practice further than to point out the general characteristics that determine the costs, but it may be pertinent to mention in a general way the methods in use underground. The Butte ore is all opened by vertical shafts which at present have attained depths of from 1800 to 2800 ft. Levels are run out at intervals of 100 to 200 ft. A large amount of work is necessary to discover and develop the ores and many thousand feet of exploring drifts and crosscuts must be run through country rock in pursuit of the various ore shoots. Here is an item estimated at 30 cents a ton for exploration work that is quite absent from the prominent Lake Superior copper mines.

In stoping, the walls are found to be soft enough to require constant timbering, usually by square sets. In many places the effect of the faults above mentioned has been to produce rock so soft as to make the timbering especially difficult and expensive. As a rule the stopes require, in addition to the timbering, a rock filling for safety. This filling is obtained mainly out of exploring drifts and to some extent from the surface, but also in some cases it has been found necessary to make rooms in the country rock for the mere purpose of securing waste filling. It does not appear that a great deal of waste is sorted for filling out of the vein itself, although it suggests itself to the casual visitor that this is a point that might be gone into rather seriously. Since the cost of transportation, concentrating, smelting, refining, and marketing amounts to at least $4 a ton, it would seem as if the point at which ore already broken would better be left in the mine than treated is about 1¼ to ½ per cent. copper.

All the mines of Butte are run on the same principle; when you describe one you describe them all. I select the Anaconda mine as a basis for comparison with the Calumet & Hecla in Lake Superior, not for the purpose of drawing any invidious comparisons of management, but for the purpose of calling attention to the factors which I believe establish the costs per ton. In such a comparison it is, of course, absurd

Appraisement of Cost Factors at Anaconda and at Calumet & Hecla

	Calumet & Hecla	Anaconda	Difference against Anaconda
Cost at Mine—			
Stoping labor	$1.10	$1.65	$0.56
Exploration	....	0.30	0.30
Supplies including timber	0.50	0.90	0.40
General expense	0.22	0.50	0.28
Total	$1.82	$3.35	
Construction and amortization	0.40	0.40	
	$2.22	$3.75	$1.53
Outside Costs—			
Freight to mill	$0.15	$0.15	
Cost of concentrating	0.55		
Cost of smelting	....	2.90	2.35
Cost of refining and marketing	0.50	1.21	0.71
Total cost	$3.27	$7.86	$4.59

Percentage milled, Calumet & Hecla mine, 100; Anaconda 90.
Percentage smelted, Calumet & Hecla mine 3; Anaconda mine, 45.
Pounds copper to ton, Calumet & Hecla mine, 42; Anaconda mine, 63.

to lay claim to accuracy, but since the object of this discussion is to find out why costs are different in different places, it seems proper to enumerate what reasons one may see.

The accompanying table shows the reported costs for the various mines at Butte from 1903 to 1907. Two facts are worth noting; First, that the cost for mining proper tended to rise, probably on account of an increased proportion of development work undertaken in the later years; second, that the cost of reduction and also of refining and marketing came down notably. This reduction is probably due to the great metallurgical improvements that have been effected by reason of the liberal policy of the Amalgamated Copper Company in its expenditures to provide better smelting facilities and also its good management. A further reason for diminishing costs in smelting, refining, and marketing is a diminution in the metallic contents of the ore, a greater amount being concentrated and a less amount being smelted and refined per ton. In the case of the Boston & Montana a considerable saving has also been effected in transportation costs.

Costs at Montana Copper Mines

ANACONDA COPPER COMPANY

(Transportation to Anaconda 26 miles)

	Tons	Mining per ton	Freight to smelter per ton	Reduction per ton	Refining—marketing per ton	Total cost per ton
1903	1,392,835	$3.49	$0.15	$2.39	$2.30	$9.23
1904	983,001	3.73	0.15	3.82	1.96	9.66
1905	1,473,644	3.56	0.15	3.00	1.11	7.82
1906	1,521,310	3.63	0.15	2.27	1.08	7.13
1907	1,401,948	4.47	0.16	2.52	0.93	8.08

BOSTON & MONTANA

(Transportation to Great Falls)

1903	907,227	$2.61	$1.00	$3.05	$2.90	$9.54
1904	988,866	2.89	1.00	2.53	1.81	8.23
1905	1,138,307	2.91	1.00	2.21	1.69	7.81
1906	1,209,805	3.45	0.93	2.45	0.90	7.73
1907	1,156,785	3.93	0.76	2.67	0.92	8.28

BUTTE & BOSTON

(Transportation to Anaconda)

1903	245,333	$3.27	$0.16	$2.44	$1.12	$6.99
1904	202,286	3.42	0.17	2.67	1.05	7 31
1905	260,433	3.31	0.19	2.45	0.79	6.74
1906	246,593	3.51	0.20	2.06	1.25	7.02
1907	331,629	3.79	0.21	2.27	0.85	7.22

BUTTE COALITION

1906	149,101	$3.94	$0.60	$3.94	$2.50	$9.98
1907	412,169	5.49	0.29	2.29		

NORTH BUTTE

1906	259,650	$4.47	$0.20	$4.84	....	$9.51
1907	374,632	4.53	0.20	4.04	.....	8.77

It is to be noted that the Butte & Boston ores have cost less than the others. This is undoubtedly due to their lower grade, the proportionate cost for smelting, refining, and marketing being less. On the other hand, the North Butte has cost more on account of its higher grade, and Butte Coalition has cost more than the average on account of the large expenditures for improvements.

The following discussion refers to a mine at Phoenix in southeastern British Columbia, where the external conditions are not unlike those of Butte, but the underground conditions very different. The inference which might be taken from the remarks in the first edition that the Granby property was over-valued was soon proved to be justified. The mine is now nearly exhausted.

Granby Consolidated (1918).—The Granby Consolidated Mining, Smelting and Power Company, Limited, British Columbia, has mined in three years 1,995,948 tons and treated 2,088,381 tons. The ore yielded by actual extraction 24.2 lb. copper, 0.38 oz. silver, and 0.06 oz. gold per ton. The silver and gold are worth $1.42 per ton, equal to about 10 lb. copper. The total value, therefore, is equivalent to a little more than 34 lb. copper, and this may be taken as a safe basis for figuring the economic performance of the mine. The ore is chalcopyrite disseminated through limestone altered by magmatic waters so as to form an approximately self-fluxing gangue. The ore will not concentrate, but is smelted in bulk. A large part of the mining has been done in open pits with steam shovels.

This company does not issue a good report to its stockholders. The statement is too brief; it contains no estimate of ore developed, nor does

COSTS PER TON AT GRANBY

	Per Ton
Current operating cost; mining, smelting, refining, and marketing for 2,088,381 tons treated	$3.39
Current construction 2,088,381 tons treated	0.36
Brought forward	$3.75
Return of $14,000,000 invested in lands and equipment at 5 per cent. interest and 5 per cent. annual amortization; this being sufficient to extinguish the investment in 15 years with an output of 11,200,000 tons	2.00
Total	$5.75

it give any intimation of the probable life of the mine. The reports give no figures about the capital invested in lands as distinguished from capital in equipment. On these accounts it is possible that the costs indicated may not do the property justice.

On this basis the selling cost of copper or its equivalent in New York is about 17 cents a pound.

It is stated in the reports that a maximum capacity of 3500 tons a day, say 1,200,000 tons a year has been provided. If this volume of operations can be maintained for fifteen years the amortization charges on the invested capital may be computed at about $1.16 per ton on 18,000,000 tons. This will equal 3½ cents per pound copper and the total cost required to neutralize the investment is 14½ cents per pound. The idea can be expressed somewhat differently, as follows:

Cost of copper for current operation and construction per lb.	11 cents
Profit per ton required to return capital in 15 years with 5 per cent. interest	3.5 cents
Total cost required at maximum output for 15 years to make the investment justifiable	14.5 cents

It is pertinent to remark that this is what I mean in all cases by amortization; but in other illustrations I have attempted to amortize only the capital invested in actual plant, while in the case of the Granby the amortization covers the entire investment in lands and property besides plant.

The Granby Consolidated in Later Years

During the past ten years this concern has re-established itself by opening up a new mine in North British Columbia, known as the Hidden Creek property at Anyox. The situation is rather interesting, an arm of the sea at about 55° north latitude. The average rainfall is about 90 inches in a year. Most of it occurs from October to March. The summer months, from April to September inclusive, are comparatively dry, the rainfall being only about 21 inches or 3½ inches per month. The mean temperature for the year is about 47°, which, by the way, is three degrees higher than that of Flagstaff, Arizona. The dampness of the climate makes the woods exceedingly thick and the surface of the ground is almost universally covered with peat. In this damp climate the destruction of vegetation by the sulphur fumes is infinitely greater than in the dry regions of the south; for miles around the smeltery the forest has been killed, giving the landscape, which is naturally very attractive, a sad and desolate appearance.

The Granby Company has had the peculiar experience of operating only on a smelting basis. Its first considerable mine, situated in South-

east British Columbia at Phoenix, gave a low-grade smelting ore, on which no milling has ever been done. The Hidden Creek mine is also operated entirely by smelting, although its ores scarcely average 2¼ per cent. At both plants these operations have been carried on with great efficiency, but it is a very open question whether it is, after all, the proper method. About 40 per cent. of the ore is almost pure sulphide, carrying about 3 per cent. copper, and 60 per cent. of sulphide mixed with greenstone and carrying 2 per cent. copper or less. The ore reserves as of June 30th., 1918 were estimated at 10,481,000 tons averaging 2.29 per cent. In 1916, 722,620 tons was treated yielding 33.30 pounds copper per ton and about 30c in gold and silver. The cost of smelting and converting is given at $1.80 per ton, but to this, I suppose, should be added for depreciation about 50 cents more, making a total of $2.30 per ton or something like 7 cents per pound of copper. The cost of mining, including development and transportation to the smelter was probably about $1.30 a ton or 4 cents per pound of copper. The sum of these costs was about 11 cents which carries the metal up to the stage of blister copper and to it must be added freight and refining and general expenses, making the total cost in 1916 about 13 cents.

There is reason to doubt that these results may be obtained indefinitely; one reason being that up to the present all the ore has been obtained through tunnels. There will presently be an additional cost of mining for hoisting. The ore, of course, is obtained in a wholesale manner and whether this can be continued down to great depths is more or less open to question. The orebodies are similar in size to those mined for many years by the Alaska Treadwell group, the description of whose operations is given in another place; but where finally the whole enterprise came to a sudden end by the caving of the mine which let in the sea water. This latter danger is not present at Anyox.

But, as matters stand, an extraordinary amount of ore is taken out per man per day; something like 6 tons. At the smeltery about 4 tons is treated per man. In November, 1917, about 1200 men were employed in all at Anyox and produced about 30,000,000 pounds copper per year. If this is a representative output we might count on about 25,000 pounds of copper per man per year, which is nearly as good as that of the Calumet and Arizona mines of Bisbee.

The full development of a property like this requires a great deal of capital. The country abounds in water power which is only partially developed. The present development is satisfactory only for a portion of the year. During the winter when the streams are partially dried up by frost it is necessary to use some steam. The water power costs about 4 mills per K. W. H., and the steam power about 5 times that much. In treating low grade ore this difference is important. The total amount of power required for mining, smelting and town lighting is about 28 K.W.H.

per ton. Since the yield is only about 35 pounds copper per ton the water power would only cost about one-third of a cent per pound but the steam power would cost $1\frac{1}{2}$ cents per pound. To obtain a sufficient supply of water power for the whole year would justify a considerable outlay of capital.

The amount of coke required to smelt the ore is about 9 per cent. Of late I am informed that this coke has been costing $14 a ton, twice as much as before the war. This is almost prohibitive for it means about 4 cents per pound of copper for fuel alone.

It would seem as if the most likely way to reduce such costs would be to concentrate the ores, or at least such portion of them as can be concentrated. But this also requires a large investment. It is said that the major portion of them may be successfully treated by flotation at a recovery of about 80 per cent. With cheap power it would seem as if this might be done at a reasonable cost and the saving in smelting would be very great indeed.

All these operations present a curious contrast with those of most of the copper mines of the western United States or of any part of cordilleran region for that matter. Anyox is situated on an admirable harbor, open all the year round; the mines are within two miles of the smelter; transportation to the United States and to all portions of British Columbia and southeast Alaska, is conducted through protected deep water channels, a little dangerous it is true on account of strong currents and rocky shores, but on the whole exceedingly cheap. Ores, coal, coke and supplies might be carried by specialized ships such as those used for iron ore on the Great Lakes when the volume of traffic becomes great enough to justify it. There is no geographical reason why Anyox should not be made an important smelting center for various ores or concentrates that might be obtained along the coast. The development of transportation in the manner just mentioned would seem to add greatly to its present advantages.

From all these conditions it seems to me that the outlook for the Granby company is encouraging. The principal requirement is the gradual and wise investment of sufficient capital.

As matters stand the capital invested in real estate, timber land, machinery, buildings, dwellings and equipment as stated in the report for 1918 is about $9,000,000. It is probable that most of this should be charged to the Hidden Creek operations, although it was probably not all spent there. The old plants in Phoenix are of doubtful value. The mines, smelters and other equipment at Anyox cost a total of $6,000,000. That is only $6 per annual ton.

The probability of the extension of these operations is largely determined by the geology of the region. The orebodies at Hidden Creek seem to be in most respects similar to the large sulphide copper deposits

in the southwest. They are on the periphery of a green-stone intrusion through states, probably of Jurassic age and are on a scale quite comparable to those of Jerome, Arizona, though not so rich in copper. The country has been extensively eroded but apparently not deep enough to carry away the cream of the mineralization. The great coast range, particularly of British Columbia is, indeed, very extensively eroded along its main axis where great intrusions of granite have cut through formations of moderate geological age, but on both sides there are many smaller ones which have scarcely penetrated through the sedimentary rocks. The geology has been only roughly mapped, but it appears that the area of this great batholith is almost equal to that of the State of New York. According to the maps it is 800 miles long. The sum total of minerals around such a mass as this must be great, but how much of it is commercially available may only be guessd at.

CHAPTER XVIII

COPPER MINES IN VARIOUS DISTRICTS

TENNESSEE COPPER CO.—UTAH CONSOLIDATED—MOUNT LYELL IN TASMANIA—NORTHERN CALIFORNIA—FIRST NATIONAL IN 1908—GREENE CANANEA IN 1908 AND LATER—WALLAROO AND MOONTA—FISSURE VEINS AT GLOBE, ARIZONA—OLD DOMINION—ARIZONA COMMERCIAL.

In the following chapter, as well as in others, there are retained from the first edition some remarks about mines based upon records which are now antiquated. I have not been able to revise them. In some cases the mines themselves have nearly, or quite, gone out of existence. Nevertheless, I have been surprised on several occasions to find that some of these references still have a practical value and I retain some of them in the belief that other engineers may have the same experience.

TENNESSEE COPPER COMPANY—1908

Only one mine of importance is found in the United States east of Lake Superior. It is owned by the Tennessee Copper Company, which works several large lenses of cupriferous pyrite. All the ore must be smelted in the blast furnace. For ores of this character I believe this company does the cheapest work in the world. Its reports are excellent and reveal not only the operating costs in detail, but also the plant expenditure and the ore in sight.

The external factors are favorable. Fuel is cheap and transportation to markets much less than for western mines. Wages are about 20 cents an hour, but I do not believe this means cheap labor.

The internal factors are favorable, with the exception of the necessity of smelting all the ore. This is a most powerful element of high cost. The ore yields only 32½ lb. copper to the ton.

The current operating costs for 1907 were as follows:

Mining	$1.22
Smelting	2.14
Administration, etc.	0.49
Total	$3.85

To this I think should be added 21 cents a ton for the use of the mining plant and 47 cents a ton for the use of the railroad and the smelting plant, making a total of $4.53.

In detail these costs are as follows:

Development	$0.1318	
Mining, hoisting, etc.	0.9389	
Crushing and sorting	0.0804	
General	0.0851	
Total current cost		$1.2162
Add cost of preliminary development amortized in 15 years at 5 per cent. interest and 5 per cent. annual amortization		0.06
Mining plant similarly amortized		0.15
Transportation to smelter	$0.1329	
Blast furnace	1.6279	
Engineering and laboratory	0.0628	
General	0.0852	
Converting	0.2402	
Total current smelting cost		$2.1430
Add amortization of smelting plant and railway as above		0.47
Add administration, shipping, refining and selling expenses		0.49
Grand total		$4.5292

On the basis thus figured, anything received above 12 cents a pound for copper in New York is applicable to dividends, and anything above 14 cents is net profit after allowing for the return with interest of money invested in the plant. These costs are higher than the average by from 5 to 10 per cent. The costs for 1907 were high on account of unfavorable economic conditions throughout the country. It should be explained further that in addition to the copper the sulphur is being utilized so that in future the property will not be wholly a copper mine. Its operations will be nearly equivalent to those of the Rio Tinto Company in Spain.

The subsequent history of this concern has been unfortunate. Copper is no longer the chief product. Sulphuric acid is being made at the rate of 300,000 tons a year and sold under a long term contract at pre-war prices. The result has been disastrous. The ore bodies are holding out well however at the 1200 ft. level, and the development of the fertilizer business gives an assurance of future earning power. Acid is being made under the high prices of 1919 for about $5.00 a ton and copper for about 20 cents a pound.

Utah Consolidated—1908

This company has mined since 1899 large deposits of cupriferous pyrite at Bingham, Utah, averaging by actual recovery for five years 60 lb. copper, 1.33 oz. silver, and 0.104 oz. gold per ton. The silver and gold are worth about $2.88 per ton, so that with copper at 14 cents per pound there is a total metallic extraction equivalent to 80 lb. copper. The ore occurs in large lenses or shoots in limestone. It is approximately self-fluxing, there being a moderate excess of iron over silica.

Most of the mining has been done through adit levels. The mining plant is not extensive. The ore is delivered to the railroad over an aerial tramway about 12,000 ft. long. It is transported by rail about 25 miles to the smelter.

The external conditions are, for the Rocky Mountain region, good, and the internal factors, with the single exception of the requirement of smelting all the ore, very favorable for cheap work. The ore is soft, uniform, and occurs in good-sized bodies. The stoping is done in square-set rooms. The item of timbering must be one of the chief mining expenses.

There is nothing in the reports to show the mining or smelting losses; but with this exception the reports are excellent. They give the stockholders in brief but sufficient outline the costs and financial results of the business.

In the five years ending December 31, 1907, the costs were as follows:

Costs per Ton for Five Years, Utah Consolidated

Mining, 1,260,453 tons	$1.73
Development, 1,400,000 tons	0.30
Transportation, smelting, and refining, 1,276,393 tons	2.80
General expense, 1,276,393 tons	0.23
Current construction, 1,276,393 tons	0.34
Amortization at 5 per cent. interest and 5 per cent. annual amortization of $1,232,274 invested in plant at beginning of period; this being sufficient to retire the investment in 15 years—proportion for five years	0.48
Total cost	$5.88

Recollecting that the ore contains in copper, gold, and silver the equivalent of 80 lb. copper to the ton, we get an average complete cost of producing copper of 7.35 cents per pound. This may be divided as follows: actual operating cost, 6.75 cents; allowance for return of working plant, 0.60 cents. Of course, everything received above 6.75 cents for copper or its equivalent in New York goes to the stockholders as dividends.

The report of the Utah Consolidated for the year 1908 exhibits conditions that are not comparable with certainty to those of former years. The smelter, which was the principal plant asset of the company, had to be permanently shut down on account of a decision of the court to the effect that its operation was inimical to the agricultural interests of the Salt Lake valley. In 1908 the ore was treated at the Garfield smelter of the American Smelters Securities Company, under terms that the Utah Consolidated believes to be unfavorable. Certain deductions were made from the metal contents of the ores under this contract. The exact amounts deducted are not stated.

On the face of the returns the record for the year was disappointing. The costs were as follows:

Mining 248,215 tons	$461,711	$1.86
Ex. and development	73,441	.30
Mine plant	3,869	.01
Smelting and transportation	921,239	3.71
Depreciation and general	127,569	.52
Current construction	129,621	.52
Add refining and marketing, bullion actually produced	120,400	.48
Total operating	$1,837,850	$7.40

Copper metal, lb	10,648,243
Silver, oz	265,284
Gold, oz	23,441

At the prices current during the year this equals 15,225,000 lb. refined copper. This is 61.4 lb. per ton. Dividing the operating cost of $7.40 per ton by this amount we get 12 cents as the cost of copper per pound.

The ore reserves have been increased so that there is no reason to change the amortization charge of 48 cents a ton given above. This, on account of the diminished yield of the ore is now equal to about 0.8 cents per pound. Adding this we get 12.8 cents as the selling cost of copper for the year.

Needless to remark that this showing is disastrous and undoubtedly the stockholders will await with impatience the inauguration of new smelter arrangements, which, it is announced, will be provided by the new International Smelting Company.

Subsequent History of Utah Consolidated

Following the inference made in the last paragraph the operating results in the next few years were not very encouraging, but later, through the discovery of bodies of lead ore, the securing of satisfactory smelting rates, and the pursuit of a liberal plan of development the property regained its earning power and has been profitable ever since.

	Copper Ore	Pounds Copper	Lead Ore	Pounds Lead	Profit
1909	280,637	10,043,900	......	....	$ 154,267
1910	182,204	7,489,471	......	....	65.348
1911	162,522	9,162,023	8,305	3,311,000	438,430
1912	159,143	6,506,814	24,243	8,732,000	603,923
1913	181,077	7,710,668	70,889	19,208,000	630,828
1914	153,345	7,584,391	48.492	14,588,000	565,665
1915	207,119	8,836,091	65,129	17,777,000	1,128,122
1916	360,034	12,211,118	74,542	18,175,000	1,924,176
1917	226,536	7,968,165	58,247	13,014,000	723,323
1918	221,651	8,476,197	31,725	812,000	252,763
	2,134,068	85,988,838	381,372	102,419.000	5,486,845

It appears that approximately 2,500,000 tons of ore, of which the copper ore as above ran only 2 per cent. and the lead ores 13 per cent., in each case carrying say 1.5 ounces silver and $1.50 in gold, have been made to yield profits of $2.20 per ton. In 1915 the costs were about as follows;

		Per Ton
Mining	$565,000	$2.10
Development, 20,000 ft. at $8.30	166,000	0.60
Smelting	706,000	2.60
Administration, etc	42,000	0.15
Refining, etc	131,000	0.48
Total cost about	$1,610,000	$5.93

In 1911 the ore reserves were estimated at only 300,000 tons, but it will be noted that 1,800,000 has been mined since—a good example of the fallacy of valuing mines on ore reserves.

Mount Lyell

The Mount Lyell Company operates a cupriferous pyrite mine and a smelter in western Tasmania. The original Mount Lyell deposit was a great mass of nearly pure iron pyrite containing only 0.6 per cent. copper, but a portion of it had been enriched near the surface. This deposit has been mined almost wholly from an open pit. Another mine, however, called the North Mount Lyell produces a much more siliceous ore averaging 6 per cent. copper. This ore has to be mined underground. During the four years, 1905–1908, which will presently be reviewed, about 60 per cent. of the ore has come from the Mount Lyell proper and 40 per cent. from the North Mount Lyell.

The external factors are probably nearly average for English-speaking countries. The climate is rainy, but nor more so than Cornwall or Scotland. The mine is situated near the coast, so that supplies must be reasonable in cost, and transportation of copper, even to England, must cost less than transportation of western American copper to New York.

The internal factors are, for a smelting enterprise, very favorable. The ores are mined, thanks to the large proportion obtained from the open pit, for less than $2 a ton. The smelting is largely pyritic and the proportion of coke used in the charge is said to be only one per cent.

In four years 1,690,531 tons were mined. In the same period the ore reserves diminished from 4,666,000 to 4,107,000 tons, a loss of 559,000 tons. At this rate of loss the property would last thirty years, but since (1) a large part of the low-grade pyrite which hitherto has been mined from open pits must be taken at greater cost from underground and, (2) there does not seem to be a first-class reason to believe that the rich ores of North Mount Lyell can be found in the same abundance for a long

period, it seems safer to estimate a life of twenty years as the amortizing period of the investment. On this basis we may compute the costs as follows;

COSTS PER TON AT MOUNT LYELL

Mining 1,690,531 tons	$1.05	
Stripping 1,690,531 tons	0.26	
Developing 1,131,258 tons	0.50	
Total mining		$1.81
Smelting 1,698,793 tons	$1.78	
Converting 1,698,793 tons	0.34	
Railway expenses	0.27	
Freight and marketing	0.72	
Total for smelting, refining, and marketing		$3.11
General expense, 1,698,795 tons	$0.25	
Use of plant; being 5 per cent. interest and 3 per cent. amortization for four years on average invested (£376,000)	0.35	0.60
Total cost		$5.52

The actual returns of metal from the Mount Lyell ores have been 34,210 long tons copper, 3,056,231 oz. silver, and 91,815 oz. gold. The extraction has been 86 per cent. copper, 99 per cent. silver, and 105 per cent. of the gold estimated by assay to be contained in the ore. There is no statement as to whether the ore treated is given in long tons or short tons, but it is probably safe to assume that the copper output is given in long tons. We have on this basis a recovery of 45.5 lb. copper, 1.8 oz. silver, and 0.054 oz. gold per ton of ore treated. The gold and silver are worth $2.18 per ton, at average prices. This is the equivalent of 15½ lb. copper, and we may figure the metallic contents altogether as equal to 61 lb. copper. On this basis the cost per pound of copper is 9 cents.

NORTHERN CALIFORNIA COPPER MINES—1908

During the last twelve years a considerable output of copper has been obtained in Shasta County from a number of pyrite deposits that are described as occurring in zones of intensely crushed granitic porphyries. The pyrite masses have been considerably enriched by the leaching of copper from the upper portions and the deposition of it in a lower part of the same deposit. It is to be inferred that the original pyrites, below the zone of enrichment, are pretty low grade, probably too low in many cases to be payable. The following description of the industry is copied from the report on the "Production of Copper in 1907," by L. C. Graton of the U. S. Geological Survey. The output of copper for that year is stated at 28,000,000 lb.

"The ores smelted in 1907 yielded approximately 3 per cent. of copper.

The yield per ton in gold was about $1.30 and in silver 2.1 oz., or $1.40, which combined are equivalent to 4.5 cents per pound of copper. In the aggregate several million tons of ore are blocked out in the mines of the Balaklala, the Bully Hill, the Mammoth, the Mountain, and the Trinity companies. The limits of these orebodies are now pretty well defined, and it is doubtful if new bodies can be discovered as rapidly as the present ones are exhausted. The first large body to be worked in the district, that at Iron Mountain, is now nearly worked out, and in spite of the fire which has been burning for several years practically all the ore will be extracted.

"Most of the orebodies thus far discovered are developed by workings not more than 500 ft. deep, but the Great Western workings, in the Afterthought district, exceed this depth, and in the Bully Hill district the lowest level is about 900 ft. below the outcrop. Owing to the rugged topography, tunnels afford easy access to the orebodies, but in a few places winzes from these tunnels are required. Open cutting is employed in part at the Balaklala and the Afterthought mines. Water is not troublesome. Up to the present time square setting has been chiefly employed. At the Mammoth mine the horizontal slicing system, with subsequent caving, is employed, and the quantity of timber required, which was large at the start, is gradually being lessened. Methods requiring less timber may be employed in the mines that are now in the development stage. Native timber is used. Electric power is employed almost exclusively and is derived from the lines of the Northern California Power Company. Much of the coke comes from Australia. The Southern Pacific Railroad crosses the district. The Iron Mountain and Hornet mines are connected with it by a private railway, and the Mammoth by an aerial tramway, which has been replaced by a combination steam and electric road. An aerial tram connects the Balaklala and Trinity mines with the Balaklala smelter at Coram. The Sacramento Valley and Northeastern Railway was completed to the Bully Hill district early in 1908. Work has been begun on a line to the Afterthought district. European labor is employed chiefly.

"Pyrite smelting is now applied almost exclusively to the ores and is very successful. Even the zincky ores of the Afterthought region are handled by the aid of a hot blast. Some experiments are under way to save the zinc now lost at this plant, and some steps in this direction may be undertaken at Bully Hill also. The Mammoth Company was the largest producer of the year, but turned out only matte, which was converted at the United States smelter in the Salt Lake Valley. The construction of converters, as well as of two additional blast furnaces, however, was practically completed in 1907. During that year the fine ore was shipped mostly to sulphuric-acid works near San Francisco, where the resulting cinders were smelted for their copper. The Mountain

Copper Company, owing to the raising of the injunction against its Keswick plant, treated part of its output at that smelter and part at its works at Martinez, on San Francisco Bay, where it has, in addition to a small electrolytic refinery, a sulphuric acid and fertilizer plant that utilizes phosphate from Utah and Idaho. The Afterthought smelter shipped its matte to Utah for conversion. Some Shasta County copper ore was treated at the Garfield smelter. The Bully Hill smelter, which has been idle since early in 1906, was enlarged and equipped for pyritic smelting. A reverberatory was also added for the treatment of fines. Work was actively carried on by the Balaklala Company in the construction of its new 1500-ton smelter until October, when construction was stopped, not to be resumed until 1908. This plant, which will treat the Balaklala and Trinity ores, will make matte, which may be converted at the Mammoth works pending a decision regarding the resumption of construction of the San Bruno smelter."

The United States Smelting, Refining & Mining Company gives no information worth speaking of about its operating results. This is unfortunate, for their Mammoth mine is now the largest producer in Northern California.

The only report I have seen upon the mining operations of this district is that of the First National Copper Company. This concern took over in 1908 the stock of the Balaklala Consolidated Copper Company, which had evidently been organized on an inflated basis. The new company with a paid-up capital of $1,500,000, bought all the stock of the old one, which was capitalized at $10,000,000. The comparison of the balance sheets of the two companies is rather amusing. The First National Company has no liabilities to speak of except its own capital stock, and no assets except the capital stock of the Balaklala, each amounting to $1,500,000. Turning to the Balaklala balance sheet we discover "Mines and Mining Property" put down at $8,688,777.05. This item was evidently a fancy price put upon the undeveloped and unequipped mining claims—a good example of mining finance in boom times. It is also a good example of the wisdom of keeping the item of real estate, the opportunity to mine, out of one's computations of mining cost.

Other assets on the Balaklala balance sheet undoubtedly represent investments, as follows:

Cost of outside properties		$37,015.77
MINE CONSTRUCTION:		
Air drill equipment	$ 24,759.23	
Locomotives and cars	18,956.23	
Aerial tramway and connections	202,499.21	
Buildings	49,985.49	
Teams and equipment	1,699.43	
		292,899.59

SMELTER CONSTRUCTION:		
Smelter	$873,682.30	
Converter	102,512.60	
Steam railroad	83,279.41	
Teams and equipment	3,931.28	
		1,063,405.59
Property in dwellings, etc		88,346.55
Total plant		$1,481,667.50
There is in addition working capital in inventories, supplies and cash, approximately		$600,000.00

We might fairly add to this about $400,000 for the cost of developing the mine and then the total cost of starting the enterprise will amount to approximately $2,500,000.

The president of the company has the following to say in the first annual report:

"During the year we operated the mine for sixty days and the smelter for fifty-two days. In the commencement of operations we expected to find a number of things that would require alterations and would more or less delay us in getting down to a working basis. I am glad to say that we are gradually overcoming all difficulties and are now producing blister copper.

"Attention is called to the fact that we only operated part of two months and one full month, and our expenses are for three full months.

"Commencing operations we had considerable waste in opening our drifts, which has reduced the value of our ores, but all indications are that the ore developed will average about 2.7 per cent. copper, 0.025 oz. gold, 0.75 oz. silver.

"Our costs, based on present operations, will be materially reduced when we are mining and smelting to our capacity of 1250 tons of ore per day."

At average prices the ore above mentioned would contain the equivalent of 60 lb. copper per ton. It is not stated whether this is the actual yield, or only the assay value from which losses will have to be deducted.

While it is manifestly unfair to calculate costs on the interrupted operation of only three months, I give the following costs for what they are worth:

BALAKLALA CONSOLIDATED COPPER COMPANY—SUMMARY OF MINE OPERATIONS OCTOBER, NOVEMBER, AND DECEMBER, 1908

		Cost per ton
Development	$1,452.47	$0.077
Mining	29,866.14	1.593
Compressor	787.93	0.042
Air drills	1,199.62	0.064
Mine tramway	1,807.31	0.096
Timbering	1,620.97	0.089
Power	1,560.36	0.083
Shop's expense	245.64	0.013
General expenses, including taxes and insurance	4,250.02	0.227
Carried forward	$42,790.46	$2.284

Brought forward	$42,790.46	$2.284
Surface and road repairs	118.03	0.006
Repairs to buildings	197.31	0.010
Stable expense	438.10	0.023
Steel sharpening	666.36	0.035
Special construction	1,244.00	0.066
Total cost	$45,454.26	$2.424

Ore mined, 18,751 tons.

SUMMARY OF SMELTER OPERATIONS

OCTOBER, 11 DAYS NOVEMBER, 11 DAYS DECEMBER, 31 DAYS

	Amount	Cost per ton of ore
Converters	$1,750.77	0.070
Blast furnaces	51,095.00	2.035
Matte and slag casting	4,454.52	1. 77
Repairs to plant buildings	1,444.51	0.057
Repairs to ore bins	2,110.78	0.084
Railroad—operation and maintenance	2,697.14	0.108
Unloading custom ore	1,190.72	0.047
Sampling mill for custom ore	887.75	0.035
Sampling mill for sulphides	2,253.35	0.089
Lighting, electric	1,148.75	0.045
Water supply and pumping plant	424.78	0.017
Assay office	800.44	0.032
General expenses, including insurance and taxes	3,199.48	0.128
Total expense	$73,457.99	$2.924
Ore smelted, 25,121 tons	66,961.50	2.665
Furnace products on hand—Total cost (see Balance Sheet)	$140,419.49	$5.589
Operating tramway		0.304
Total cost per ton		$5.893

Assuming that the 60 lb. mentioned above represents recovered metals, these costs indicate operating costs of about 10 cents per pound. To this will have to be added an annual charge of 6 per cent. on $1,500,000 for depreciation of plant expressed in construction, equal to $90,000 a year. General expense, including taxes, insurance, and administration, will be $35,000 more. On an output of 250,000 tons these items will be 50 cents per ton and the total operating cost of copper will approach 11 cents.

The amortization of $2,500,000 invested in the property with 4 per cent. interest at 15 cents copper and 11 cents cost, equaling 4 cents a pound profit, with an output of 15,000,000 lb. a year, will require five years operation, 1,250,000 tons of ore, and 75,000,000 lb. of copper. Whether the company has this amount in sight or not is not stated.

GREENE CONSOLIDATED, CANANEA, MEXICO—1908

This company has a very large property near the Arizona border in the state of Sonora, Mexico. In 1906 the Greene-Cananea Company

was formed to consolidate the old Greene Consolidated Copper Company, and the Cananea Central Copper Company. The management has been completely reorganized.

The record of the old Greene Consolidated Company was as follows:

Output and dividends	Greene Consolidated	
	Lb. copper	Dividends
1901	28,826,854	$400,000
1902	38,268,407	
1903	42,310,544	600,000
1904	55,014,339	1,200,000
1905	63,005,848	2,800,000
1906	55,943,739	1,200,000
	283,369,731	$6,200,000

The dividends are up till March, 1907.

It appears that up to that date the dividends, which must represent approximately the earnings, were equal to 2.19 cents per pound copper produced. If we count as copper the value of silver and gold produced, the earnings per pound would be about 2 cents. Since in those particular years the average price of copper was about 14.9 cents, we may conclude the average cost to have been about 12.7 cents; and since at the end of the period it was found necessary to undertake large improvements, it is altogether probable that something should be added for depreciation.

No estimate of the amount of ore in sight is given in the report for 1908.

The report goes into the question of mining costs so thoroughly and with so much good sense and poise that I quote largely from the statements of the general manager, Mr. L. D. Ricketts. It will be seen that the reduction of costs in all departments has been enormous. But it occurs to me to point out one or two reasons for accepting with a little caution the conclusion that the process of reduction is so firmly intrenched that further reductions are inevitable.

First, let me note that during 1908 the monthly tonnage treated was about 60,000 against nearly 100,000 in former periods. It is just possible that the reduced tonnage may have great advantages over the full tonnage in that it is secured with *selected labor* and from *selected places.*

Either of these advantages may be of great consequence in the matter of costs, as has been pionted out in the chapter on the Value of Mining Property. It comes as an example of how costs go down in periods of depression.

Second, it is worth considering whether the period under review does not get great advantages from the reconstruction that preceded it. All

plants were overhauled and renovated. It is natural to suppose that in consequence everything was in excellent repair—better than average. As to charging up current construction to operating, that is something that always must be done sometime—whether the cost sheets show it or not. There is no great virtue in doing it in this particular case because in this very year, outside of what was charged to operating, there was spent on plant no less than $820,000 or 5½ cents per pound of copper produced from the company's own mines.

Furthermore, let us consider the following. At average prices for the last ten years (15.4 cents copper, 57 cents silver, and $20 gold) the ore for 1908 shows the following values.

Copper	53.4	lb. =	$8.22
Silver	0.923	oz. =	0.54
Gold	0.00575	oz. =	0.115
Total			8.87 = 57.6 lb. copper

The costs for 1908, the lowest on record, are $5.976 per ton. This gives 10.37 cents per pound for the copper, or its equivalent, extracted. With these costs, the profit per pound is 5 cents and we might expect a profit, under average conditions, of some $2.80 per ton mined and treated. With these comments the following is quoted directly from the report.

THE CANANEA CONSOLIDATED COPPER COMPANY, S.A.

AUDITOR'S REPORT

December 31, 1908

Earnings

Total earnings on copper, gold and silver, and net earnings from miscellaneous revenues	$2,427,335.79
Expenditures	
Total expenditures account copper, gold, and silver	1,821,029.85
Net profit for year	$606,305.94
Sundry expenditures including shut-down costs, etc.	820,446.56
Deficit for the year 1908	214,140.62

REPORT OF GENERAL MANAGER

The figures of production are for the period beginning July 11, 1908, when operations were resumed, to the close of the calendar year. In reading this report I would respectfully refer you to my report of February 15, 1908.

Tonnages

Wet tons domestic ore treated	295,554
Wet tons custom ore treated	72,088
Total	367,642

Ratio of concentration, domestic ore milled	3.12 tons into 1
Ratio of concentration, custom ore milled	4.02 tons into 1

Production

Returnable fine copper in domestic bullion	15,679,685 lb.
Returnablr fine copper in bullion from custom ore	2,939,924 lb.
Total	18,619,609 lb.
Silver in domestic bullion	272,651.24 oz.
Silver in bullion from custom ore	175,011.99 oz.
Total silver	447,663.23 oz.
Gold in domestic bullion	1,700.683 oz.
Gold in bullion from custom ore	1,178.150 oz.
Total gold	2,878.833 oz.

Recovery from Ores.—Recovery from domestic ore and other material treated was as follows;

Copper 2.652 per cent. Silver 0.923 oz. Gold 0.00575 oz.

The value of the precious metals per ton of domestic copper produced amounted to $21.09.

Development during period: January 1 to December 31, 1908:

Shafts	412.5 ft.
Winzes and raises	3,550.5 ft.
Tunnels, drifts, and crosscuts	9,388.0 ft.
Total	13,351.0 ft.

The Mines.—The following statement covers the tonnages and costs of mining at the various mines;

	Wet tons	Total cost	Cost per wet ton
Puertocitos	18,465.4	$41,549.68	$2.250
Elisa	40,481.4	71,580.00	1.764
Capote	15,923.1	82,088.64	5.155
Oversight	142,824.8	272,766.63	1.910
Veta Grande	91,901.3	191,992.54	2.089
Total	309,696.0	659,997.49	2.131

The Cost of Mining.—The cost of mining for the total tonnage mined was $2.13 per wet ton. For the fifteen months ending October 31, 1907, it was $3.28, and for the year 1905–1906 it was $3.85.

Great credit belongs to the Mining Department for this showing under most difficult conditions. The reasons for the decreased costs are twofold. First, the slicing and carving system has been thoroughly learned and applied to the various mines in the modified forms which the conditions demand. This has resulted in a decreased amount of timber and supplies and an increased efficiency of the men. The second reason is that the Mining Department has been entirely reorganized and the average pay per employee has been decreased by this readjustment very nearly 20 per cent. We have, therefore, a decreased cost per man and an increased output per man. For the period in question the output per man has been increased from 1.2 to 1.6 tons, and this covers not only the miners but the muckers, trammers, blacksmiths, and in fact every employee of the mines up to and including the foremen. It is hard to realize the difficulties that have been encountered in accomplishing this, but it had to be done and was done.

Departing from facts and predicting for the future, I have little doubt that we will be able to maintain and improve upon these costs in spite of the tremendously increased amount of development work we propose to do, and we can look to continued decreases in mining costs rather than increases for some time to come; but in saying this I am keeping in mind certain capital expenditures which are exceedingly urgent. This construction provides cheaper compressed air and more electrical power at the mines. You have authorized and we are now installing an air compressor of 6000 cu. ft. of free air per minute capacity at the power house and will lay a pipe line to four of the mines and replace with this one machine eight uneconomical small machines. Since the reverbertory furnace is generating an average of over 600 boiler horse-power we have a surplus of boilers at the power house and no new boilers are needed, and our power house condenser is abundantly large to take care of this compressor. In addition to this we are now up to the limit of our electrical generating capacity and it is essential that we should put in more power for the use of the mines. Mr. John Langton, consulting engineer, is now making a study and report on our power equipment, and is preparing specifications to be submitted to you. It would appear that with an expenditure of $57,000 we can increase our capacity 1000 kilowatts and reduce the cost of generating power per kilowatt year about 15 per cent. If this unit is put in there is no question but that other capital expenditures will be required, because if we can change over our steam hoists of four of our shafts to electrically driven hoists by the addition of the proper motors we can abandon entirely four very expensive steam plants. If the program is approved and carried out it will require a total expenditure of about $120,000. In making this recommendation I have carefully considered the tremendous expenditures that we have had to make and am still keeping in mind the rule of recommending only expenditures that will pay for themselves in one year's operations.

In the first edition further quotations were made from Dr. Ricketts' report for 1908 but for present purposes it seems desirable to substitute

PRODUCTION AND PROFITS OF MINES OWNED AND CONTROLLED BY GREENE-CANANEA COPPER CO., INCLUDING CUSTOM ORES.

	Copper, lbs.	Silver, oz.	Gold, oz.	Price copper, cts.	Profit
1911	44,897,466	1,295,297	5,892	12.886	$1,318,472
1912	48,157,847	1,457,308	7,197	16.019	2,580,750
1913	44,480,514	1,497,938	8,021	15.1	2,344,592
1914	21,858,920	907,310	6,054	13.838	638,955
1915	16,335,081	635,997	3,773	19.566	1,410,543
1916	62,250,067	1,975,734	11,692	25.541	7,673,184
1917	30,496,487	891,226	5,754	27.038	2,497,888
	268,476,382	8,660,810	48,383		18,464,384

an outline of the subsequent history of the concern. Several points in this experience are worth attention; for instance, the correctness of Dr. Ricketts' anticipation of being able to maintain the improved operating results, the difficulty of keeping up satisfactory industrial enterprises in a county of unstable politics, and the comparison of Mexican labor with American labor.

Up to the end of 1915, that is before the war introduced any change beyond peace time precedent, the profits aggregated about $8,300,000 from a total of about 175,700,000 pounds copper, about 4¾ cents a pound. But it appears that some of the metals reported was from custom ores, from which the profit was presumably small. The exact amount of such metals is not entirely clear but it appears to be about 28,000,000 pounds copper, for the five years 1911–15 inclusive. The total amount of copper therefore, from which the overwhelming preponderance of the profits must have come was only about 148,000,000 pounds, with 5,000,000 ounces silver and about 27,000 ounces gold. Under the prices then prevailing the gold and silver averaged about 2 cts. per pound of copper, making the total value expressed in that metal about 18 cents. The average profits were about 5½ cents, equal to about a third of the recovered value, leaving say 12½ cents per pound for cost.

The dividends paid in the period 1911–15 from the above stated earnings, of $8,300,000 were about $5,885,000, about 70 per cent. of the earnings, but the difference is quite accounted for by the growth of $2,124,000 in current assets in four out of the five years. We may therefore conclude that the profits reported are a real excess of receipts over expenditures.

The unstable political condition of Mexico is pictured in every report; not so much by description as by the bald references to repeated shutdowns, resulting in fluctuations of output between 16 and 62 million pounds. That the costs under such conditions should remain so constant as is shown by the following record is not a little remarkable.

COSTS OF GREENE-CANANEA OPERATIONS FOR A PERIOD OF YEARS

	Tons	Mining	Reduction	Total
1905–6	947,977	......	......	$10.21
1906–7	1,305,291	......	......	7.625
1908–6 mos.	295,554	......	......	5.976
1909	835,929	......	......	5.459
1910	792,856	......	......	5.765
1911	741,873	$2.52	......	5.257
1912	895,406	2.927	$2.848	5.925
1913	757,460	2.890	2.546	6.73
1914	439,587	3.09	2.678	7.02
1915	312,196	2.46	2.715	7.82
1916	1,238,151	2.61	2.395	7.95

There is reason to suppose that the totals reported for 1912 and before cover not quite the same items as those reported later; perhaps they cover only operating costs while the later ones cover also general expenses of all kinds.

The reduction of the ores is interesting. The grand average yields about 45 pounds copper, 1.4 oz. silver and 16 cents gold, per ton. In 1916 about 70 per cent. was smelted direct, the remainder concentrated, chiefly by flotation. Concentration cost, in 1916, 84 cents a ton. The cost of operating the reverberatory furnaces, per ton of charge, was $1.67. We may suppose that the total expense of treatment per ton of new ore before the war was divided somewhat as follows:

Concentrating 30% at 84 cts.	$0.25
Converting 45 lbs. at ½ ct.	0.23
Refining and marketing about.	0.70
Roasting and smelting	2.30

Total about $3.48, equal to about 7½ cents per pound of copper alone, and to about 6 cents per pound if we convert the precious metals into their equivalent in copper.

The cost of mining is exhibited in the table and averaged perhaps $2.80 per ton. A little over 15 tons is mined per foot of development. The cost of development is not always reported but for 1913 it figures out about $8.00 per foot.

The number of men employed in 1916, which was a full year of operating, was 3643 Mexicans and 188 foreigners, a total of 3831. The output per man per year was about 15,000 pounds of copper alone and about 17,000 pounds if we convert the precious metals into their equivalent in copper. This output per man is less than that at any of the neighboring districts in the United States, as will be seen for the figures given for those districts. About one ton was mined, concentrated and smelted per man per day; and the total cost per man was about $5.00 a day.

Wallaroo and Moonta

An example of conditions and costs similar to those of Butte is furnished on the other side of the world by the Wallaroo and Moonta mines of South Australia. These mines have not been described with the definiteness one would like; but in a general way the first is a group of fissure veins in metamorphic schist and the second a similar group of fissures in porphyry. The production of the district has not been so large as that of Butte, and the mineralization is less intense. The mining costs are somewhat higher because exploration is more expensive, but in other respects the parallel with the great Montana camp is close and interesting.

These mines are described by the general manager, H. Lipson Hancock (son of the inventor of the Hancock jig) in a pamphlet issued at Wallaroo, in November, 1907. The mines were discovered in 1860. In forth-seven years these mines have raised and extracted as follows:

Dressed ore and concentrates	1,670,360 tons.
Copper, averaging 15 per cent. in ore	248,993 tons.
Total value	£13,944,445
Total cost	£11,285,809
Total dividends	£ 2,018,254
Average cost per ton of concentrates	£6 15s. 2d.

"The dressed ore of Wallaroo," says Mr. Hancock, " has throughout recent times averaged about 11 per cent.; that of the Moonta about 20 per cent. of copper, excepting that in later years it has been 2 or 3 per cent. lower. For a long time the vein stuff as raised to surface at both properties has contained on the average from 3 to 4 per cent. copper."

Port Wallaroo, the smelting point, is situated on the west side of the York peninsula. The Moonta mines are twelve miles south and the Wallaroo mines six miles east of the port. The ore comes from about ten different veins in all. At the Wallaroo mines there are three large veins and several smaller ones in metamorphic mica schist supposed to be of Cambrian age.

Most of the work has been confined to one lode along which were occurrences of copper near the surface for a length of 10,000 ft., but at the the depth of 2000 ft. the length of workable ground has contracted to 2500 ft. On the other veins the ores did not prove remunerative below the 1000-ft. level. At Moonta there are five veins of which only one is holding out below the 2000-ft. level. In both groups the copper is largely in the form of chalcopyrite mixed with iron pyrite. The ore occurs in rather short shoots, often where the vein is intersected by cross-courses.

The high cost for mining is easily explained. There are more than eighty miles of development openings, including shafts, drifts, etc. This

work would probably cost at least $12 a foot, or $5,000,000. This accounts for $3 per ton of dressed ore, or approximately 75 cents per ton of vein stuff hoisted. The actual stoping, including hoisting, pumping, etc., costs about $3.50 per ton. The ground is soft like that of Butte, probably softer, requiring close timbering as well as close filling. The granulated slag from the smelter is used for filling.

Sorting and milling in 1903 cost 75 cents at the Wallaroo and $1.25 at the Moonta. These costs seem high, but the work is done with extreme care.

In terms of short tons and American money I find that the average cost of mining, concentrating, and smelting a ton of concentrates for the whole life of the mine has been $32.90. In recent years the cost has exceeded this by about $2 per ton. The increased cost is to be explained by the increased depth and a certain deterioration of the mines.

The accompanying table gives the cost of the complete operations for six out of the last ten years. The reports are excellent.

Costs of Operation at Wallaroo and Moonta for Six Years

			1,176,000 tons crude	292,889 tons concentrates
General expense	Interest and discount	$0.07	$0.58	$2.33
	Adelaide office	0.07		
	Special funds for employees	0.04		
	Depreciation and redemption	0.40		
Mining and milling	Wages and contracts	4.20	$5.68	$22.81
	Machinery and materials	0.55		
	Fuel	0.44		
	Buildings	0.04		
	Water supply	0.04		
	General and miscellaneous	0.41		
Smelting	Freight on concentrates		$2.37	$0.52
	Wages			3.73
	Machinery and supplies			2.33
	Fuel and flux			3.02
	Buildings and improvements			0.15
	General and miscellaneous			0.28
	Shipping copper			0.49
Total			$8.63	$34.66

Mines on the Old Dominion Lode, at Globe, Arizona

The following remarks from the first edition are retained, with a few modifications to remove some misconception.

Old Dominion Copper Mining and Smelting Company

This famous property has been working for many years on a fault fissure of rather complex geological relations in the Globe copper district of Arizona. It has not published any detailed reports that have come to

my attention prior to the one for the year 1908, which gives some information about the two preceding years. The information is exceedingly interesting for the additional light it throws on the problem of copper mining on fissure veins. It belongs to the same class of mines as those of Butte and the Wallaroo and Moonta.

PRODUCTION OF COPPER—INCLUDING CUSTOM ORE

In 1905	15,103,955
1906	16,653,225
1907	23,377,841
1908	30,308,223
Four years	85,443,244

The silver and gold with the ore are so small in amount as to equal in value less than 2 per cent. of the copper.

The yield of copper was 2.83 per cent. in 1906, 3.88 per cent. in 1907, and 5.15 per cent. in 1908.

Development Work.—For three years 1734 ft. of shaft sinking and 55,261 ft. of drifts, winzes, and raises, a total of 56,995 ft., were done on the property. It is not stated that the ore reserves were greatly increased by this work, so that we are led to calculate that each foot of development opens up a little over 14 tons of ore and about 1230 lb. copper. The cost of development per foot can be inferred. It is $15.70 per foot. The cost of shaft sinking must be high, owing to the considerable amount of water. If the drifts, raises, and winzes average $12 a foot, the shaft would cost about $125 a foot The development costs $1.90 per ton mined and 2.14 cents per pound copper.

MINING COSTS

	1905	1906	1907	1908
Development	$0.8792	$1.1436	$0.9853	$1.1571
Pumping	0.5354	0.5470	0.4331	0.6356
Mining (from stopes to surface)	4.2514	4.4929	4.9152	4.5449
Total	$5.666	$6.1335	$6.3336	$6.3336

Concentrating.—In 1908 about half the ore was concentrated. This ore ran 3.036 per cent. copper and 3.019 tons were put into 1 with as extraction of 82.5 per cent. Hence we may conclude that the concentrate ran 7.5 per cent. copper.

Total Operating Results.—It appears that in 1908 the total cost at Globe for mining, concentrating, and smelting, deducting profit from custom ores, was $3,108,351. The tonnage mined is given at 225,227

tons dry, with a yield of 105 lb. per ton. This ore would only yield 23,600,000 lb. The total amount of copper produced was 30,300,000 pounds, the remainder custom ores. On this basis we get the following:

225,227 tons mined at		$6.3336 =	$1,427,383.83
294,750 tons	Concentrated and smelted at	5.703 =	1,680,968.
	Refined and marketed at	1.590 =	471,597.
		$13.6266 =	$3,579,948.83

These are the best costs I can make out of this report. If the ore contains 105 lb. copper equivalent per ton, then the cost per pound is 13 cents.

These conclusions are borne out by the more extended history of the company which is now available. It is probable that in its whole history of nearly 40 years this company has produced about 500,000,000 pounds of copper.

From 1905 to 1915 inclusive, the yield was probably about 220,000,000 pounds and the dividends about $7,400,000, equal to 3.4 cents a pound. The costs must have been about 12 cents, about $10.80 cents a ton. The ore has seldom risen much above 5 per cent. in grade and often falls below it. In 1917 it averaged 4.97 per cent. in 1918, 4.52 per cent.

Since 1908 the proportion of development work has been increased to 1 foot for every 10 tons extracted. Heavy pumping and close timbering are required. Under these circumstances it is doutful if mining costs ever got much below $5.50 a ton.

Mines East of the Old Dominion

So far as I can gather the Old Dominion vein is not a simple or unmistakable fissure, but is an assemblage of branching fissures, each of which is a fault of rupture of the rocks, along which the opposite rock masses have moved more or less. Each intersecting fissure therefore is in itself a plane of adjustment and carries with it some more or less important change in the characteristics of any other vein that it meets. Thus for instance, the walls of the main fissure at the Old Dominion mine have moved past each other about 1100 feet, but going eastward this movement has been so distributed among branch fissures that by the time the Iron Cap is reached the movement between the walls is only 300 to 350 feet. It seems probable that other branches may have taken up a larger part of the movement and might be argued to be "the" Old Dominion vein. The principal claim for the Iron Cap to that distinction is that it contains large bodies of good ore and lies in the same general course as the more pronounced and more valuable parts of the Old Dominion.

Arizona Commercial

The total productive length along the Old Dominion lode or zone, is about 2½ miles. The Arizona Commercial lies immediately east of the Old Dominion.

It has shipped in the four years 1915–1918 inclusive, 195,743 dry tons of copper ore and report that they have developed "probably upward of 600,000 tons, averaging more than five per cent. copper." This would give that company a total production, mined and unmined, of something over 600,000 tons, which would yield a total of about 68,000,000 pounds copper. Since this property is only 1740 feet long, these figures indicate a production of more than 450 tons of ore and nearly 40,000 pounds of copper per running foot.

Arizona Commercial Mining Co.

Year	Dry tons	Per cent. copper	Development, feet	Cost including Boston office	Cost pumping	Cost without pumping	Cost per ton without pumping
1915	44,333	4.872	4,326	$227,638	$35,609	$192,029	$ 4.33
1916	48,890	5.028	4,442	339,578	49,689	289,889	5.93
1917	39,703	6.15	3,545	353,771	69,519	284,252	7.16
1918	62,797	5.87	5,729 est.	712,000	70,000	642,000	10.20 est.
	195,943		19,042				

The cost for mining in 1918 is not reported as in the preceding years and I have been compelled to estimate it by trying to dissociate it from the smelting costs with which it is lumped. I cannot vouch for the accuracy of the figures thus obtained, but they fit in pretty well with general experience. They indicate a rise of cost of 40 per cent. in 1918 over 1917.

CHAPTER XIX

LEAD

Lead mining in general—Division into three economic types—Disseminated ores—Fissure veins—Ores resulting from concentration of mixed sulphides—Production of lead by states—World's production—Smelting plants.

Lead Mining.—While a geological description of lead deposits would be rather tedious and difficult to make, a classification of lead ores from an economic standpoint is easy. As in the case of copper they fall naturally into three groups.

1. Disseminated sulphide ores that can be concentrated in a high ratio, *i.e.*, where far the greater part of the material mined can be discarded mechanically as waste, leaving only 3 to 10 per cent. to be smelted
2. Fissure vein deposits, almost always carrying an important amount of silver, and often gold and copper. Such ores concentrate in a moderate ratio. From 10 to 35 per cent. must be smelted.
3. High-grade bunches of carbonates or sulphides already concentrated by nature so that the ore must be smelted as mined, the only rejection of waste being by hand sorting.

Without going much into detail it will be interesting to pursue the characteristics of these ores a little further.

1. In the United States practically the only disseminated ores are those of the Mississippi Valley region, principally in Missouri. They have been deposited by waters circulated from the surface downward, and depositing lead ores in the beds of limestone most favorable, through their chemical or mechanical structure, for the reception of such ingredients. These deposits are invariably sharply limited in their extension downward. They are confined to certain beds that the geologist can soon recognize. The horizontal extent may be very great, sufficient to give these deposits. great importance and a long prospective life. The southeast Missouri district is by a good margin the most productive in the world. Here the mining conditions are closely parallel to the copper districts of Lake Superior and to the newly developed disseminated copper ores of the West. This holds good as to costs. As in the case of copper ores of this class, the total cost of production per ton of ore was before the war between $2 and $3. The lead ores of this class are about three times as rich as the copper ores, hence the cost of lead is only one-third the cost of the copper; a fact that, as a corollary, holds good with regard to the selling price of the metal.

2. The fissure vein deposits are for the most part original deposits caused by hot waters ascending along fissures from great depths. The fissures of the Cœur d'Alenes were not simply open cracks in the rock, they were more apt to be crushed zones where the circulation of water was often brought to a stop by the infiltration of minerals and again started by renewed fissuring. There were thus several distinct periods of mineralization. Sometimes the successive mineralizations were of the same character, sometimes of quite diverse characters.

In the case of the principal deposits of the Cœur d'Alenes the lead ores were deposited at the expense of, and replacing, certain iron carbonate that had been deposited earlier. The iron carbonates had often replaced large quantities of the original quartzite rock in the fissure zone. After the lead had been deposited there was a recurrence of deposition of the iron carbonates which attacked some of the lead sulphides. All these complicated processes were of deep-seated origin. After the real mineralization had all ceased the orebodies were exposed to the effects of the circulation of surface waters. As the surface was slowly eroded away the air-carrying waters from the surface reached gradually deeper and deeper into the original deposits, attacking and rearranging the minerals enriching some parts of the orebodies and impoverishing other parts.

In the Cœur d'Alene mines, the effect of the last process upon the value of the ores was not very great. The oxidation did not affect the veins more than a few hundred feet down from the outcrops. The far greater portion of these deposits is original, the surface action has nothing to do with the depth limit of profitable mining. That limit is quite unknown. Wherever the end of an orebody has been found the geological reason for it has either been that the fissure entered a different and less favorable rock formation, or else the reason for termination is obscure. Certain formations of quartzite are now recognized as being far more favorable for the deposition of lead ores than others. With this sole limitation the Cœur d'Alene veins promise to be productive to very great depths.[1]

Other great lead-bearing fissures have a somewhat different character. The great Broken Hill lode in Australia, which has produced more than $325,000,000 in gross value of lead and silver, from which over $60,000,000 has been paid in dividends, is mineralogically as much of a zinc deposit as a lead deposit, though the proportion of silver is nearly the same as in the Cœur d'Alenes. At Broken Hill the effect of surface waters in rearranging the minerals was of capital importance. Although the original ores have been proved to be payable, the metallurgical difficulties encountered upon passing from the oxidized zone into the unaltered sulphides were so serious as to bring the development of the mines for a time almost to a standstill. A brief further description may be interesting.

The Broken Hill lode is one of the greatest mineral deposits of any

[1] This was written in 1909 and is retained for its historical interest. See chapter on Silver-Lead Mining.

kind in the world. It is certainly the greatest of its class. It is some 2½ miles in length and contains ore shoots as much as 300 ft. thick of massive ore averaging some 35 per cent. in lead and zinc sulphides. The geological relations of the mass are somewhat obscure. At one time it was thought to be conclusively proved that it was a "saddle reef," *i.e.*, a bed folded back upon itself so as to form a deep trough, approximately lenticular in cross-section and plunging to the south. I believe doubt has been thrown on this explanation, which seems a little improbable. At any rate it is a huge, highly mineralized mass, acting in all essential respects like a fissure vein, in a region where the rocks are highly metamorphosed and compressed.

The original minerals seem to be in the proportion of lead sulphides, about 15 per cent., zinc sulphides about 20 per cent., with a gangue of quartz, calcite, garnet, and rhodonite. The metallic assays are lead and zinc, each about 13 per cent., and silver 5 to 10 oz. per ton. In the lower parts of the mine the ore forms a hard compact mass, containing no waste, in which the valuable minerals are closely knit together with the gangue, making the concentration and separation of the metals difficult, expensive, and unsatisfactory. But the surface waters, to a depth of from 250 to 400 ft., had removed the zinc and left a bonanza orebody containing 33 per cent. lead and 20 to 30 oz. silver; an ore of easy metallurgical treatment accessible to mining in an open pit. At the surface, therefore, the realization of the values presented no difficulties even in the Australian desert; but when it suddenly became necessary to separate a lessened percentage of lead from an obstinate accompaniment of zinc (for the two metals cannot be smelted together), facing at the same time a loss of half the silver, in a region where water was scarce and everything expensive it required a good part of the money earned from the surface bonanza to solve the problem. It required nothing short of discarding the old smelting plants altogether and beginning anew; worse than that, experimenting with new processes. The outcome has been that the original ores have proved to be payable, but to a diminished degree. Lead can no longer be produced so cheaply, while the great masses of zinc ore, formerly discarded, have become valuable and a formidable factor in the zinc market. Under no circumstances, however, can the original ores become anything like so valuable as the altered surface ores (except, indeed, through their much greater volume).

Lead ores from such fissure veins as the above bear a close economic as well as natural resemblance to the copper ores from fissure veins. It will be noted that the costs in the Cœur d'Alenes and at Broken Hill, per ton, are not far from those of the copper mines of Butte, of Wallaroo, and Moonta, and of the Old Dominion at Globe, Arizona. The total cost for the whole process is from $6 to $10 per ton. As noted in the case of disseminated ores, the lead is about three times as abundant as copper, justifying prices inversely proportional.

3. The third class of lead ores, simply smelting ores, are nearly always of an origin similiar to the surface ores, just described, of Broken Hill. They are usually the result of the reconcentration of mixed sulphides of iron, zinc, lead, and copper. It very often happens that the original ores are quite unpayable, owing either to their low grade, or to the fact that their volume is insufficient to warrant the expensive installations of plant necessary to work them. Lead ores of this kind usually form an insignificant fraction of the ore deposits from which they are derived, but often they are of high grade both in lead and silver, are near the surface, and can be mined profitably even in small quantities. For this reason a considerable amount of lead and silver is derived from a multitude of small shipments of this kind of ore, from hundreds of different places. In some few cases, such as Leadville, Colorado; Tintic, Utah, and Park City, Utah, such ores have been important sources of lead. In those camps the rich lead ores have been the principal resource of some of the mines. A certain amount of concentrating ore is obtained with the high-grade ore, but in each case, if the high-grade ore were absent, the lower grade ore would not be payable. Other districts producing this type of ore are Eureka and Pioche, Nevada; Aspen and Creede, Colorado, and Santa Eulalia in Mexico.

I shall give no very clean-cut examples of the cost of mining these ores. Those of Park City will give a general idea. The cost per ton in general for this class is high, certainly not less than $20 per ton for mining and smelting. In Park City the cost is between $10 and $15 for mining alone, to which must be added for freight, smelting, refining, and losses from $20 to $25 a ton more, making a total of $30 to $40 a ton.

Ores of this class bear a close parallel in manner of occurrence, methods of exploration, and high costs to the similarly derived copper ores of Bisbee, Arizona.

The above table will show at a glance the sources of lead supply in the United States and their comparative importance. I propose in the following pages to give an idea of the state of the business in Missouri, Idaho, and Utah. These three states produce more than 80 per cent. of the total for this country. A chapter is added by Mr. W. R. Ingalls (*The Mineral Industry*, 1908) on Silver Lead Smelting in the United States, to show not only the relations of the Western mines to the custom smelters of the country, but also the business results of the American Smelting and Refining Company, by far the largest factor in the smelting, refining, and marketing of lead and precious metals in North America.

The above table and paragraph are retained to show by comparison what changes in the business and in the production have taken place since. The following later statistics from the reports of C. E. Siebenthal for the United States Geological Survey entitled "Lead in 1916" bring out some additional facts. It will be noted particularly that the relative

production by various states has not changed materially. It is estimated that up to the end of 1916 some 12,558,000 tons of lead had been produced in this country, with a value at New York of $1,138,000,000, equal to $90 a ton or 4.5 cents per pound. That for 10 years 1905–1915 inclusive,

PRODUCTION, PRICE PER POUND, AND VALUE OF REFINED LEAD IN THE UNITED STATES, 1720–1916.

Year	Desilverized lead *a*, *b*, *Short tons*	Soft lead *c*, *Short tons*	Total production *b*, *Short tons*	From domestic ores and base bullion *b*, *Short tons*	From foreign ores, *Short tons*	From foreign base bullion, *Short tons*	Price per pound at New York	Value
1720–1905	5,251,079	2,081,836	7,332,915	6,032,383	1,300,532		....	$634,403,000
1906..........	313,886	90,860	404,746	336,200	28,803	39,743	$0.057	46,141,000
1907..........	313,588	99,801	413,389	352,381	24,041	36,967	0.053	43,819,000
1908.	295,552	101,012	396,564	311,666	11,509	73,389	0.042	33,311,000
1909..........	329,751	117,158	446,909	352,839	21,754	72,316	0.043	38,434,000
1910..........	328,954	141,318	470,272	375,402	18,065	76,805	0.044	41,384,000
1911..........	331,032	155,947	486,979	391,995	10,764	84,220	0.045	43,828,000
1912..........	339,646	141,248	480,894	392,517	11,572	76,805	0.045	43,280,000
1913..........	330,593	131,867	462,460	411,878	13,223	37,359	0.044	40,696,000
1914..........	383,903	158,219	542,122	512,794	7,639	21,689	0.039	42,286,000
1915..........	388,594	161,461	550,055	507,026	9,581	33,448	0.047	51,705,000
1916..........	403,619	167,515	571,134	552,228	6,085	12,821	0.069	78,817,000
	9,010,197	3,548,242	12,558,439	10,529,309	2,029,130		....	1,138,104,000

a Desilverized soft lead is included; for quantity see page 841.
b Antimonial lead is excluded; for quantity see page 842.
c Desilverized soft lead is excluded.

WORLD'S PRODUCTION OF LEAD, 1910–1916, IN SHORT TONS

Country	1910	1911	1912	1913	1914	1915	1916
Australia..................	108,907	109,789	118,387	127,867	107,520	113,733	152,762
Austria-Hungary..........	19,290	21,605	23,589	26,565	....	....	....
Belgium..................	44,864	48,832	56,438	55,997	51,220	18,485	17,150
Canada..................	16,535	11,795	17,968	18,849	18,465	22,700	21,000
France..................	22,266	26,014	34,282	30,864	....	....	....
Germany..................	174,604	181,218	194,666	199,627	....	....	....
Great Britain.............	32,628	28,660	32,187	33,620	22,248	17,659	14,000
Greece..................	18,519	15,763	15,983	20,282	23,166	12,986	10,555
Italy..................	15,983	18,408	23,699	23,920	22,920	24,429	27,200
Japan..................	3,858	4,630	4,960	3,968	5,111	5,336	12,500
Mexico..................	133,048	137,347	132,276	68,343	31,000	62,000	30,000
Russia..................	1,323	1,102	1,102	1,102	....	....	....
Spain..................	211,531	193,013	205,799	223,767	158,207	192,049	165,095
Sweden..................	441	1,213	1,433	1,653	1,564	2,148	2,324
Turkey in Asia............	13,999	13,668	13,779	15,322	....	....	....
Other countries *a*..........	17,306	22,597	13,448	6,834	11,814	7,750	12,410
United States (domestic refined)..................	375,402	391,995	392,517	411,878	512,794	507,026	552,228
	1,210,504	1,227,649	1,282,513	1,270,458	....	....	....
United States percentage of world production.........	31.0	32.0	30.6	32.4	....	....	....

a Includes Burma only, 1914–1916.

PRIMARY LEAD SMELTED OR REFINED IN THE UNITED STATES, 1907–1916, BY SOURCES, IN SHORT TONS

Source of ore	1907	1908	1909	1910	1911	1912	1913	1914	1915	1916	1917	1918
Domestic ore:												
Alaska	....	3	69	75	51	45	6	....	358	659	884	....
Arizona	2,418	1,464	1,507	948	3,428	3,891	4,901	5,601	6,953	15,328	7,456	6,252
Arkansas *a*	15	....	14	....	15	....	....	52	51	170	300	34
California	938	515	977	1,207	615	811	3,294	3,698	5,606	3,633	11,471	6,686
Colorado	52,552	28,729	30,865	38,542	30,442	37,039	42,840	41,198	32,352	33,046	29,327	32,150
Idaho	123,292	98,464	103,747	109,951	117,335	127,780	137,802	177,827	160,680	170,059	174,045	145,424
Illinois *a*	498	362	273	263	308	513	619	427	910	670	867	2,273
Iowa *a*	225	110	15	....	....	....	....	34	....	....	....	....
Kansas *a*	1,798	2,293	2,763	1,308	2,522	1,937	1,504	1,043	1,320	1,737	2,663	7,252
Kentucky *a*	75	....	....	50		91	16	16	95	37	21	....
Missouri *a*	122,856	122,451	141,105	161,659	182,203	162,610	152,430	194,275	195,634	218,253	218,197	104,175
Montana	2,145	2,320	1,451	1,943	2,484	2,517	3,256	4,386	4,853	4,961	5,933	18,568
Nevada	3,480	3,796	4,792	2.246	1,082	5,699	6,142	5,996	7,664	11,858	12,334	11,658
New Hampshire	....	....	....	....	....	....	....	....	3	46	3,428	4,118
New Mexico	2,047	586	1,350	1,890	1,371	2,511	1,821	741	2,157	3,290	....	....
North Carolina	....	....	....	2	35	34	10	....	....	....	....	....
Oklahoma *a*	404	1,409	2,268	1,805	1,925	2,500	3,214	3,916	4,346	10,969	19,646	56,097
Oregon	5	7	7	....	11	21	37	17	11	9	....	....
Pennsylvania	....	....	....	....	....	....	....	....	6		....	....
South Dakota	....	13	....	8	33	12	7	2	5	12	34	5
Tennessee *a*	16	....	....	....	....	....	....	....	8	....	....	....
Texas	12	42	44	36	57	30	108	89	111	26	58	....
Utah	55,540	42,455	66,648	60,605	54,933	60,664	71,069	88,976	106,105	111,789	82,081	83,504
Virginia *a*	83	13	....	87	400	85	878	143	457	740	147	....
Washington	341	391	120	339	612	53	9	2	11	217	929	2,636
Wisconsin *a*	3,573	4,013	3,252	3,909	3,966	3,301	2,639	1,819	2,632	3,121	2,930	4,533
Wyoming	....	....	....	....	....	....	....	....	6	....	....	....
Undistributed	896	36	317	101	48	120	3	99	116	113	145	....
Zinc residues	1,890	1,290	1,735	2,237	1,987	3,131	3,765	4,125	4,562	5,478	6,489	....
	375,099	310,762	363,319	389,211	405,863	415,395	436,430	534,482	537,012	596,221	57[illegible],385	558,880
Foreign ore:												
Africa	288	....	3,150	3,310	582	1,774	5,976	2,942	....	328	1,748	1,519
Canada	2,607	162	66	25	122	29	16	2	1,174	1,231	1,100	7,550
Central America	23	12	20	3	28	....	....	....	1	7	....	....
Mexico	20,204	10,145	16,944	11,704	7,333	7,407	4,512	2,386	5,437	1,917	7,607	4,798
South America	919	1,186	1,536	2,996	2,677	2,332	2,617	1,821	2,829	2,366	1,533	1,101
Other foreign	....	4	38	27	22	30	102	488	140	236	3,894	84
Foreign base bullion:												
Canada	2,716	179	1,500	....	....	....	....	....	....	1,072	6,750	8,108
Mexico	34,251	73,210	70,816	76,805	84,220	76,805	37,359	21,689	33,173	11,598	39,508	76,809
South America	....	....	....	....	....	....	....	....	275	151	189	39
	61,008	84,898	94,070	94,870	94,984	88,377	50,582	29,328	43,029	18,906	62,319	100,008
Grand total	436,107	395,660	457,389	484,081	500,847	503,772	487,012	563,810	580,041	615,127	635,669	641,704

a The lead produced by these States is nonargentiferous or soft lead.

4,665,000 tons were valued at $425,000,000, equal to $91.20 per ton or $4.56 per pound. I assume that we may argue that the normal value of lead mines should be based on the profits realized under this average price.

The lead smelters of the United States are distributed as follows: California 1, Colorado 4, Idaho 1, Illinois 4, Indiana 2, Kansas 1, Missouri 5, Montana 1, Nebraska 1, New Jersey 2, Pennsylvania 1, Texas 11, Utah 3, Washington 1, Total 28.

Canada 2.

Mexico 14.

Total for North America 44 plants.

Of the lead produced in 1916 only 72 per cent. came from straight lead ores, the remainder came from zinc-lead and copper-lead ores. The average output of lead per smelter in the U. S. seems to be about 20,000 tons per year. Most of them smelt other ores with the lead but in what proportion it is hard to find out. Perhaps the average tonnage of ore treated per smelter is 100,000 tons per year.

The average content of crude lead ores mined in the U. S. in 1916 was only 5.7 per cent. Of this at least 90 per cent. is concentrated before smelting. The Cœur d'Alene concentrates run about 45 per cent. and the Missouri concentrates 68 per cent. Probably all the lead concentrates of the country average over 55 per cent. Most of the straight smelting ore is produced in Utah and by the numerous small producers outside of Idaho and Missouri where with insignificant exceptions all the ore is milled.

CHAPTER XX

SOUTHEAST MISSOURI

GEOGRAPHY OF THE DISTRICT—POPULATION GEOLOGIC HISTORY—EARLY PALEOZOIF GEOGRAPHY—THE SILURIAN MOUNTAIN RANGE OF NEW YORK. MYSTERY ON THE ORIGIN OF MISSISSIPI VALLEY LEAD AND ZINC DEPOSITS—ECONOMIC SITUATIOC —EXPLORATION—MINING—MILLING—SMELTING—PROFITS—COSTS.

There is such a thing as vogue or fashion even in the most serious affairs of life. Thus for instance it may be taken for granted that the history of Rome is interesting, but that of England dull; that it is "the thing" to know French, but not to known German, or that some dignity accrues to a family that moves from Brooklyn to Manhattan, and is lost by a family that moves from Manhattan to Brooklyn. This is true of mining districts in the same way and to the same extent and it is worth while calling attention to the fact too, because we miners have spent so much effort trying to describe our business in terms of engineering, that we may have forgotten that human nature is just the same in mining camps as it was in Imperial Rome itself. Thus certain mining districts are in a way famous and fashionable. The glamour of romance has long ago fallen over the golden streams of California and a certain glory has attached to Butte, Leadville, Cripple Creek and many other such places. Novelists have gone to them for scenery and characters; magazines, newspapers and even the stock ticker have made them everyday words to the great public. A miner boasts of having worked in the "Comstock" the foreman's wife feels prestige when she tells her guests at the table that "we come from Butte."

No such mantle of fame has ever been enjoyed by the greatest of lead mining district, Southeast Missouri. I have known ladies who had gone there from theWest because their husbands had found employment, to suffer agonies from the depression of the imagination due to the general acceptance of its commonplaceness. Arithmetic is not a secure defense against public opinion and the statistics of Flat River are not much comfort to souls that pine for the glories of Canyon Creek. I remember being amazed to find that children could be homesick for Flat River. But positive observation convinced me that they not only could be but were, and it was only by calling to mind the ancient proverb "de gustibus non disputandum est" and Polonius' sage remark that "there's nothing either good or bad but thinking makes it so," that I was able to find precedents for such a state of affairs.

But an unprejudiced observer need have no such difficulties. The

region has beauty and a strong local color; and even the romancer would have to dig no deeper there than in Butte itself to find the inter-play of hopes, ambitions, attachments and anxieties that give zest to the

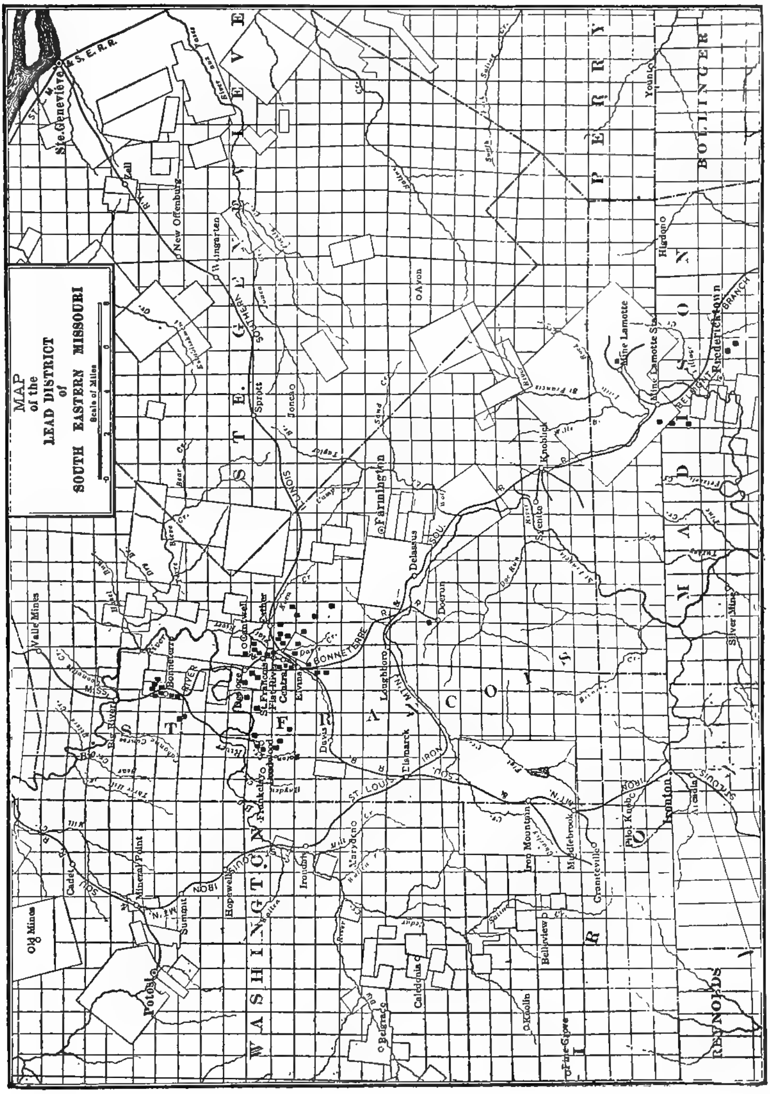


Fig. 8.

story of life. A very modern and very obscure poet has even called upon rhyme to picture the landscape of early spring between Bonne Terre and Simms' Mountain through the heart of Flat River.

> "A patch of yellow field and now a cedar glade
> Amidst the oak woods dressed in last year's dingy red,

> And by the lazy sun are frequently displayed
> Green shoots which spring is rousing from their winter bed.
> And from this ridge where now I drive my car
> Broad river vales are pictured through the oak,
> And yonder, bluish highlands rise up dim and far
> Through drawing haze and level streams of smoke.
> And here's a dusty village where stray pigs squeal,
> And chicks and children scatter as we pass;
> Where bony curs rush out as if to snap the wheel,
> And sad faced hound dogs sniff the strips of grass."

This region is near the eastern end of the great low plateau of the Ozarks, which, although made known to every school boy as a name in the geography, is not generally understood. Some geologists have given excellent descriptions of it but their books are technical and are read mainly by a few students, anxious to learn how to earn a living. To the farmers of the great rich surrounding plains of northern Missouri, Kansas and southern Arkansas, this region is dimly known as a poor country with flinty hills peopled by exceedingly queer "natives" who do not know that the civil war is over yet and who make a living by some mysterious collaboration with "razor backs" (half wild hogs), where the hills on the roads are so steep that "you must lie on your back to see up them," where the thin tires of the baling-wire-bound-together wagons have a way of coming off and wheeling themselves uncertainly away into the brush, where wood ticks and "chiggers" afford one constant company, and where fever and ague hold control of the scanty river bottoms. While a part at least of this description is intended to be facetious, it is true in substance.

But it is hardly fair to allow the Ozarks to suffer too much from the jests of their neighbors. In many respects derision is just the pot calling the kettle black. It is true that the country is rather sterile, the ridges being strewn with rough fragments of flint; in consequence many of the farms and the farmers are poor; but those rocky hills are a welcome relief to the eye wearied by the monotony of the plains where the rich farms are, and those poor farmers are of the very stock that produced Abraham Lincoln. The rocky roads are no worse than the bottomless mud ruts of Illinois; the water in the streams is often clear and much fresher than that of the neighboring plains. You will find wood ticks and "chiggers" just as abundantly near the golf courses of fashionable Long Island, where by the way, the scrubby flint hills are replaced by scrubby and monotonous sand barrens. Malaria still lingers in the swamps inside the world's greatest city and mosquitoes drift through the windows of its sky-scraping hotels. And in the Jersey highlands within fifty miles of that same metropolis I have heard of "natives" of pure and old white American stock who not only could not read and write but who could not tell the numbers on the brass checks by which they register their work days. Some of these products of a proud and free democracy have even condes-

cended to ask the oppressed Slavs of Austria and Hungary to tell them the numbers on their pay checks. All this, be it remembered, within walking distance of Princeton, Columbia and Vassar.

The poor soil of the Ozarks has retarded their development but whenever one is able to disregard or overcome that handicap, he will be disposed to think well of this region as a place of residence; far from being envious of his neighbor in Illinois he will plume himself on enjoying better water, better drainage, better climate and infinitely better scenery. And we take the point of view of the mining population of course we are not concerned primarily with the fertility of the soil. The miner of Flat River is in attractive natural surroundings. He does not enjoy the sight of snow clad mountains or the impressive fault escarpments of the Cordilleras but he has green hills and a pleasing landscape: his imagination may console itself for want of the Continental Divide by contemplating the obverse of that divide for he is only twenty-five miles from the Mississippi River. Moreover he is in the very heart of the riches of the great central valley, only sixty miles south of its metropolis. He does not have to go far to find other miners and mineral products. Barely fifty miles to the east are the coal fields of Illinois, three hundred miles west are the zinc and lead fields of Southwest Missouri, three hundred miles north are the zinc fields of Wisconsin, six hundred miles north the copper and iron fields of Lake Superior, six hundred miles east the wonderful coal fields and smelting plants of Pennsylvania and West Viriginia and the zinc mines of Tennessee; six hundred miles southeast are the coal and iron fields of Birmingham; and at lesser distances on all sides are the oil and gas wells of Illinois, Kansas, Oklahoma and Arkansas. It is true that no direct roads or common interests have seemed to lead him to exchange frequent visits with these neighbors, but that is a privilege that is wide open to him, which with his expanding opportunities and vision he may yet take advantage of. It is a fact that many a common miner of Flat River is able to take his family to visit the circus in St. Louis and return the same day in his own automobile.

Before going into the human history of this region let us see if we cannot get some picture of its natural history.

Most people would have no difficulty in understanding the salient features of geological history if they had an opportunity to observe the facts over a wide enough area. This opportunity however, is denied practically to all who do not make geology a profession. But the miner is pre-eminently a geological animal who is altering the arrangements of nature: or, to put it another way, and perhaps more correctly, he is rapidly becoming an important factor in the development of the earth's crust. To such an animal gifted with intelligence and desire to know the effect of what he is doing some training in geology ought to be a commonplace of education, just as geography is. In fact geology is a mere

amplification of geography. I do not mean the stereotyped political geography which deals with the names of countries, of cities, of counties and county seats, but with the fundamental and interesting natural geography which deals with the distribution of sea and land, of mountain systems, drainage systems, the movements of the atmosphere and of ocean waters, the distribution of heat and cold, of rainfall, of deserts, of volcanoes and glaciers, of vegetation and animal life on land and in the sea. The normal child is intensely interested in some or all of these things. With this as a foundation it would be very easy to understand and to recognize the effects which would be produced by the long continuance of the activities of winds, rivers, seas, volcanoes, glaciers, changes of level, etc. and to realize the legible evidence of these effects in the rocks, soil and landscape that one sees every day.

The Ozark region is a part of the earth's surface where the geological record is one of extreme simplicity and stability.

A few miles south of the principal lead mines is a group of granite and porphyry hills known as the St. Francois mountains. Among them are some famous old iron mines the exploitation of which was the foundation of some of the solid fortunes of St. Louis, and whose existence prompted the construction of the St. Louis, Iron Montain and Southern Railroad, now one of the trunk lines to the southwest. A casual observation shows that the St. Francois mountains are a series of rounded knobs of harder and older rock which rise up through the layers of sandstone and limestone just as islands rise out of the waters of the sea. A very little observation, properly directed, will make it plain that those sandstones and limestones do actually represent the work of the sea. This simple observation is an easy starting point from which the interested student may explore the geology of North America. Curiously enough, no! not so curiously either, for this is the usual experience in such things, this observation also leads to an understanding of many important facts about the lead mines, the iron mines, the drainage, the soil, the climate and the whole basis of life in this region. In the rocks of the St. Francois mountains and of the lead mines one may see perfect evidence of the four following facts: (1) the St. Francois mountains are part of an old land surface no doubt an earlier development of our present continent, (2) that in some manner the level of this part of the continent was lowered and the ocean which is now no nearer than the gulf of Mexi flowed in until it submerged the whole country and left the St. Fran Mountains sticking up as small islands, hundreds of miles from he nearest mainland, (3) that the sandstones are the washed and assorted debris which the advancing ocean found on the old land surface, and that the limestones are sediments deposited in the sea water probably with the help of organic life, that these materials gradually filled up this mediterranean sea, and that the process of subsidence went on slowly enough

and the agencies of deposition kept at work fast enough to keep the sea shallow most of the time or all of the time, and (4) that the period of subsidence came to an end altogether and was followed by a period of slow and vacillating elevation, which has continued for an enormous length of time but which represents on the whole an extraordinary stability of level compared with other parts of the continent, and that while the Ozark plateau has been a land surface for interminable ages the greater part of its present elevation took place in relatively recent times.

One does not have to be much of a geologist to discern that all of these statements are facts, as well and plainly recorded as any facts in human history, but when we come to another observation relating to the lead mines the evidence is not so definite or conclusive; but is a more or less well founded inference which we will call (5) that the lead ores were introduced not when the rocks were originally deposited but later by the circulation of underground waters in the long period of emergence and erosion mentioned as period (4).

It is a matter not entirely academic but of present economic interest to picture to one's self the extraordinary difference of scene one might have found if he had been able to visit the St. Francois mountains during late Cambrian times when the great Appalachian, or American Mediterranean Sea was lapping around their sides. They then looked somewhat as they do now. They have been protected through all these ages by a partial covering of other rocks which formed around them. Part of this casing has been removed, the old form returning to vision again at least as much like what it was in Cambrian times as the mummy from an Egyptian tomb is like the form of an Egyptian king. They were a group of rather abrupt rocky islands surrounded, as all such islands are, by numerous rocky islets and reefs. The main islands were rather small, not large enough for streams which would carry much gravel or sand into the sea so that the sand had only a moderate source of supply and practically all of it lay in the bottom and was now being covered up by a calcareous sand from lime which was slowly being precipitated out of the sea water.

In the bays and shallow reaches of sea on the north and northeastern coast of these islands from Big River past Flat River toward Doe Run there were extensive belts of sea weed perhaps something like the kelp belts along the Santa Barbara channel in California. Just west of Bonne Terre was a little round island of porphyry around which the waves lapped harmlessly. Off the east side of this little island there was a belt of sea weed which stretched like a fish hook three-quarters of the way around it. Only on the northwestern side there was no sea weed.

These belts of seaweed acted very much like belts of vegetation do on the surface; as the plants lived and died portions of them settled to the

bottom and formed a sort of soil in the limy bottom of the ocean. The thicket of kelp kept the currents from washing these fragments away just as a thicket of trees keeps the wind from blowing the falling leaves away. Thus in the course of time these sea weed belts became the sites of deposits of a vegetable ooze which gradually in long geologic ages became buried in the increasing deposit of limestone and other sediment. As the rocks hardened under the increasing weight and by the slow chemical interaction these patches of vegetable ooze became patches of carbonaceous shale.

I have said that a picture of the conditions under which those limestones were deposited, if corrrect, would not be wholly academic. I explain this now by adding that the belts of carbonaceous shale in the limestone are now the loci of the great lead deposits of this district. It is not impossible that if we can get a correct idea of how these shale patches originated we may get a better idea of where to look for them and a clearer perception of how much to expect from them.

The nearest mainland was probably due north in Wisconsin about 400 miles away. Over the site of St. Louis the water may have been fairly deep but this is not determinable with certainty. There are 3600 ft. of limestones and sandstones under St. Louis and under that the old granite surface of the pre-Cambrian continent has been found in a drill hole, but, as remarked sometime ago, it is more probable that the sea was never very deep, a respectable portion of its apparent depth having been filled with sediments during the process of deepening. Indeed, it is certain that this was the case.

The foregoing was written in 1917 and was interrupted by my desire to have something a little more definite to say regarding the geography of Cambrian times. But a little excursion into geological literature soon convinced me that that was no subject that the text books had a matured answer for. The more I read the less I knew, and at last I am convinced that the only answer is a mere tabulation of facts from which some obvious inferences may be drawn.

Tabulation of Prominent Occurrences of Cambrian and Ordovician Strata

	Thickness feet
Bisbee, Arizona—Sandstones and Limestones	1,500
El Paso, Texas—Sandstones and Limestones	1,800
Central Texas—Sandstones and Limestones	800+
Grand Canyon, Arizona—Sandstones and Limestones	1,200
Southern New Mexico—Sandstones and Limestones	1,200
Central Oklahoma—Sandstones and Limestones	5,000+
Northeastern Alabama and Northwestern Georgia—Sandstone, Limestone and Shale	13,000+
Eastern Tennessee and Western N. Carolina—Sandstone, Limestone and Shale	11,000+
Western Nevada—Sandstone and Limestone	5,000

Inyo Range, Nevada-California—Sandstone, Limestone and Shale	16,300
Missouri—Sandstone, Limestone and Shale	2,000+
Eastern Pennsylvania—Sandstone and Limestone	10,000+
New Jersey—Sandstone, Limestone and Shale	Not given
New York City—Sandstone and Shale	5,000+
Boston—Shale	Not given
Wyoming—Sandstone, Limestone and Shale	1,000
S. Dakota—Sandstone, Limestone and Shale	400
St. Paul, Minnesota	1,000
Adirondacks—Sandstone, Limestone and Shale	12,000
Southwestern Montana—Sandstone, Limestone and Shale	1,250
Quebec—Sandstone, Limestone and Shale	5,000
St. Johns, New Brunswick—Sandstone, Limestone and Shale	2,800
Northern Newfoundland—Sandstone, Limestone and Shale	6,000
Canadian Rockies—Sandstone, Limestone and Shale	4—9,000
Arkansas—Sandstone, Limestone and Shale	4,000

Throughout the vast area in which these observations have been made, the Cambrian and Ordovician sediments are generally covered with later ones; they are exposed for the most part only in places where the rock formations have been bulged up above the general level so that they have been worn through by erosion. Areas in which these rocks do not occur may frequently be proved to have been merely denuded of them. By combining these facts with the long list of localities, dotted all over the country, in which these formations may be seen, and with the surprising uniformity in the character and the succession of the materials which compose them we arrive without difficulty at the conclusion that in early Paleozoic time practically the whole of the United States with large adjacent tracts in Canada was flooded by the sea; that these were none of the mountains with which we are familiar; no Atlantic and no Pacific coast. The highlands of the continent must have had an alignment nearly at right angles to that of the present time, *i.e.*, nearly east and west. It seems to be a fair guess that the principal divide was along the line of the pre-Cambrian mountain chain which may be traced from Labrador to eastern Minnesota south of Lake Superior. This chain is buried in Minnesota and westward under later sediments but it is pointing in such a way that it would, if continued, reappear in the plateau region of Wyoming or Colorado, and from thence might easily swing southwestward to north central Arizona where there is plenty of evidence of post Algonkian and pre-Cambrian mountains. A dim support to this theory is afforded by the fact that in Colorado, northern New Mexico and portions of Arizona the Cambrian and Ordovician sediments are either absent or extremely scanty. What is certain is, that the region south of this line was invaded in the course of time by the sea. It was probably a plain sloping gently toward the south or southeastward and this plain gradually and progressively became a sea floor over which the water was never profound and on which were accumulated the Cam-

brian and Ordovician sediments, the measure of which we have roughly taken.

To return to Southeast Missouri then we may be sure that when the Bonneterre limestone was forming the St. Francois mountains were at first islands which gradually became islets and finally sank completely beneath the waves; that an extensive ocean swept through without a break. I am certain that at that time a mariner might have embarked at some point between Jerome and Grand Canyon, Arizona on the north shore of either an island or a peninsula, and from thence he might have sailed freely on a clear sea over Reno, over the site of the Sierra Nevada, over San Francisco and Los Angeles, thence eastward over Tucson, Bisbee, El Paso, over the great plains of Texas and Oklahoma, over the Ozarks, over St. Louis and Chicago, Cincinnati, Buffalo, Philadelphia, New York, Boston, Montreal and Quebec.

Remarks on Paleozoic Geography

While it is probably true that the broad groupings of Algonkian, Paleozoic and Mesozoic have the meaning indicated in the chapter on coal it would be a mistake to interpret it too narrowly. Terrestrial conditions were not uniform throughout any of those times. Thus the Algonkian in Lake Superior was separated into three general periods of sedimentation, by two intervening periods of general erosion, brought about by the elevation of the region and by considerable mountain building. Similarly the Paleozoic series exhibits changes certainly on a continental, and possibly on a world wide, scale. It seems that there is a pretty sharp distinction between the Lower and Upper Paleozoic in North America. The important break, or change, occurred at the beginning of Silurian time, the disturbance being a very widespread elevation of the continent, which in the preceding Cambrian and Ordovician periods had been very generally invaded by the sea. Desert conditions supervened. A large tract of water, covering the western parts of New York and Pennsylvania, the whole of West Virginia, Ohio, and Indiana, portions of Kentucky, Illinois, southern Michigan and southern Ontario, must have been shut off from the ocean and exposed to so dry a climate that it evaporated, leaving immense salt deposits covered tightly by shales that probably represent the dust of the desert.

The immediate cause of such a revolutionary change of climate was, not improbably, the formation of an important range of mountains on the general line from the Gaspé Peninsula through Vermont, western Massachusetts and Connecticut to New York City and southwestward. It might be called the Manhattan Range, for it is as well developed on Manhattan Island as anywhere else. At present of course nothing remains of these mountains but their base-leveled core. But all the evidences of mountain building are there—sharp folding, igneous intrusions

and extensive metamorphism. The highly crystalline schists in Central Park are of upper Ordovician age; the same age to which some of the oil bearing strata of Ohio belong and younger by far than the undisturbed rocks of Flat River. The axis of the mountains is clearly shown by the metamorphism. Westward from this axis the same rocks are found in various folds, but the metamorphism disappears rapidly until at Fishkill and Poughkeepsie it has disappeared altogether; the rocks are twisted but not recrystallized.

The southward continuation of this ancient range is obscure and perhaps will remain so. At New York City it disappears under the waters and under the later sediments of the coast line, but it reappears in the vicinity of Philadelphia where it points toward the low foothill region eastward of the Blue Ridge of Virginia, and, I imagine, may have extended all the way to Georgia and Alabama, perhaps much further still. But geologists do not seem to have recognized it. They have generally supposed that the crystalline area of the foothill or Piedmont region of the Appalachians was a pre-Cambrian island or continent that remained exposed during Paleozoic time. They call this supposed island Appalachia. Some study of the literature on the subject does not convince me that there was any Appalachia in pre-Silurian times. It appears rather that it is merely a zone of mountain building and erosion. Immense masses of Cambrian and Ordovician limestones and shales are crowded into folds along its northwestern flanks. "Metamorphism increases toward the southeastward," is a common phrase in describing them. The character and thickness of these sediments, that is, their uniformity over large areas and the fact that they are generally of marine origin, are pretty strong evidence that they could not originally have terminated so abruptly along such a line. If they had these would have been evidence of shore line conditions; but the contrary seems to be the case. Moreover what does the metamorphism mean? Why should there have been metamorphism only along a supposed shore line? I prefer to believe that the evidence points to something like the following:

1. In Cambrian and Ordovician times the sea, or at least low plains partially or occasionally flooded by ocean water, spread continuously from the Atlantic over the present Appalachian highlands and far to the northward invading in fact a large part of the present continent, rather uniformly. In other words the continent became pretty well baseleveled.

2. The beginning of Appalachia was the emergence of a great mountain range in early Silurian or late Ordovician time, along the line described. This event was coincident with the general emergence of the continent, which was the cause perhaps of a general change of climate throughout the world, certainly in North America, and very likely this change had much to do with the evolution of living creatures. This

mountain range of Appalachia was a long and high one and its erosion produced much of the sediments which filled the interior valley during later Paleozoic time.

But in the lower Paleozoic time in which the rocks of southeast Missouri were accumulated it seems fair to conclude that nearly the whole of the United States was an open sea. The region later, through the emergence of distant barriers, became the central portion of a continental valley. Minor oscillations of level have at various times caused this great valley to be alternately a spreading shallow sea and a great interior plain. The climate has varied from desert to sub-arctic, probably from the effect of the barriers that have arisen and disappeared at various times. No true mountain building stresses and no volcanic activity has affected this great area in all this stretch of many million years. The rocks have been disturbed slightly but to the eye they are as horizontal as when first laid down.

In the preceding chapter it was pointed out that silver-lead deposits in the west are consequent upon igneous activity. The strange thing about the lead and zinc deposits of the Mississippi valley is that there has been no such activity within many hundred miles. But the deposits occur over a very wide area, almost wherever these lower Paleozoic rocks are found, and often in the upper Paleozoic rocks as late as the Pennsylvanian—in Oklahoma, Kansas, Arkansas, Missouri, Iowa, Wisconsin, Illinois, Kentucky and Tennessee. In the Ozark region one or two paltry dykes, quite unmineralized, have been found; barely enough igneous action to emphasize its general absence. Nevertheless there is in all these places an assemblage of sulphide minerals almost exactly like those of the magmatic deposits of the west, but in different proportions. The single exception is vein quartz. There are in places enormous quantities of chert or flint, but there seems to be little if any association of this mineral with the metallic sulphides. In many places it is completely absent. But sulphides of iron, copper, lead and zinc, with silver, nickel, cobalt, manganese and barium are widely distributed.

In the Flat River region the principal locus of the mineralization is the Bonne Terre or basal Cambrian limestone. This stratum is about 400 ft. thick. It is so generally mineralized with disseminated iron pyrites that it weathers to a bright red residual soil. This redness is decidedly more pronounced in the neighborhood of the principal lead deposits. A tract of about 15,000 acres of this limestone produces regularly a third of the lead of the United States and 12 to 15 per cent. of that of the world.

In this field the external conditions are favorable. Mining is conducted in the midst of the great agricultural regions of the Mississippi Valley, where the cost of living is low, labor abundant, fuel and transportation cheap, and markets close at hand. The internal factors also also are favorable to low costs. The depths reached are not great, the

orebodies are fairly large and persistent, though somewhat irregular. Drilling provides against underground perplexities.

In the southeast district there is, unfortunately, little to be found in the way of reports of mining companies. The following notes are from my own observation, and while I cannot vouch for the accuracy of the figures as representing any particular property, I believe that they may be taken as fairly representing the district as a whole.

Southeast Missouri Lead

Mining in southeast Missouri is based on orebodies that carry an average of about 5 per cent.[1] in metallic lead, or a little more. The ore is called disseminated from the fact that the galena is often sprinkled through the limestone, although usually most of the lead is confined to rich streaks. It concentrates well and can be turned into a 65 or 70 per cent. product, with a saving of 80 per cent. Commercially speaking, therefore, the ore yields about 4 per cent. net lead.

The formation lies approximately flat, though grades of from 3 to 10 per cent. are not uncommon. It has, throughout the district, a gentle dip toward the southwest. The ore now being mined occurs mostly in the lower 100 ft. of the Bonne Terre limestone, and often at the very bottom of this formation in contact with an underlying sandstone. Occasionally it happens that in the 100 ft. just mentioned there are successive enrichments, making workable orebodies one above the other. In this case more than one level may be necessary. But it is more common to find only one large irregular sheet of ore immediately above the sandstone, so that it can all be worked from one level; although sometimes the ore may shoot up some distance above the general level. The upper orebodies are relatively unimportant.

The ore zone may carry some lead scattered through the rock on both sides of the workable channels, which may be only 5 ft. wide. The fissures are sometimes the source of the ore from which it has fed out into the surrounding rocks. The richest ore, in such cases, is right at the fissure, and it fades out on either side, so that midway between fissures the ore may be too poor to work. The ore is workable to a thickness varying from 6 ft. to as much as 100 ft.

Explorations in the Southeast District

It will be evident from the above that the exploration of these orebodies by the sinking and drifting methods used in Western mines would be difficult and unsatisfactory. To follow the ore underground, it is almost necessary to stope the ore as you go. There is enough vertical

[1] The average is, in 1919, about 4 per cent.

irregularity to prevent following the ore successfully by horizontal drifts; and there is enough horizontal irregularity to make it impossible to keep in the channel, unless you are prepared to follow up each turn. If the ore rises you must be prepared to go up after it; if it sinks you must go down after it.

The problem of blocking ore out ahead has resolved itself entirely into diamond drilling from the surface. This varies in difficulty according to the depth. The formation dips slightly toward the southwest, while the surface rises a little in that direction. The southwestern part of the field is, therefore, the deepest part. In the older mines at Flat River, the depth to the sandstone is only 300 to 400 ft. In the newer mines like the Derby (Federal) and the Hoffman (St. Joe) the depth is 500 to 600 ft. In the deepest part, between Leadwood and Irondale, the depth is from 500 to 800 ft. When the depth is not over 550 ft., the drilling is all through very favorable rock; but where it is deeper, the cherty Potosi limestone comes in. This cherty formation is very hard to drill through, and it is best, whenever it is found, to use a churn drill through that formation, and then put in a diamond drill.

The drill is used first to find out in a general way the position of the ore channel by running a line of holes at intervals of about 200 ft. When lead ore is found that looks worth following up, holes are put in closer in the attempt to follow it in its usual course. If ore is found in considerable amount in 15 or 20 holes, enough is blocked out to justify sinking a shaft. As a general rule it is not found desirable to try to map out the orebody accurately by drilling until some progress has been made in stoping it, and more knowledge gained about its peculiarities.

Owing to the soft nature of the richer ore streaks, the drill cores invariably give an underestimate of the value of the ore. Even where ground is most carefully drilled, the actual mining shows from 20 to 100 per cent. more lead ore than the drilling would indicate. It is very common to have blank holes in the middle of a good orebody through grinding up of the ore streaks. Owing to the irregular shape of the deposit, some poor ground is apt to run into the middle of the space occupied by the ore. For these reasons it often happens that one-half the holes, even in good stoping ground, do not indicate pay ore.

The cost of drilling for many years went constantly upward, owing to the increased price of diamonds and of labor. Where drilling could be done about 1900 for 40 to 50 cents a ft., in 1907 it cost from $1 to $1.25 per ft. In the deeper holes, where the Potosi limestone must be penetrated, the cost probably averages $1.50 per ft. Subsequently events have reduced these costs again.

The above description refers especially to the mines in the vicinity of Flat River only. At Bonne Terre the orebodies are a little different, in that the longer axis there seems to extend N.E.-S.W., instead of N.W.-

S.E. These orebodies are northeast from the ore zones of Flat River. It now seems very probable that a connection will be established between Bonne Terre and the Flat River orebodies.

Extent of the District.—As remarked above, a line taken around the productive mines incloses an area of only about 15,000 acres and from this a production rising from 50,000 tons in 1900, to 100,000 in 1907 and to 200,000 in 1916 has been taken but outside of this area are a number of other places where ores of the same kind have been mined. At Doe Run, Fredericktown, and Mine La Motte are important occurrences which differ from the above-described field only in that they are in shallower basins of limestone, which are interrupted by knobs of pre-existing granite. At Fredericktown the ores carry, besides lead, copper, nickel, and cobalt. At the North American mine at that place considerable ore has been found that carries 5 per cent. copper and 2.5 per cent. nickel and cobalt. Everything indicates that there are possibilities of extension in copper mining in that neighborhood. The copper ores have exactly the same structural characteristics as the orebodies above described, except that, instead of pure galena, the ore is mainly sulphides of copper, nickel, and cobalt.

Following is the discussion that appeared in the first edition. It was probably nearly correct at that time and is retained in order to indicate later the directions in which changes have been made.

Problem of Mining in the Southeast District.—The most difficult part of actual mining operations is the preliminary exploration by drilling. This determines the depth to which the shafts must be sunk, and their location. Usually only one level is necessary, but the fact that the ore does not lie exactly flat makes some provision for hauling cars up and down hill necessary. This can best be done, I believe, by electric haulage. This has been installed at one of the Federal plants and is very effective. Provision must also be made sometimes for secondary pumping to raise water from depressions that may reach lower than the shaft-pumping station.[1]

The stoping is very simple. No timbers are used. Round pillars of ore are left, containing 10 to 15 per cent. of the ore. It is often possible to leave pillars in the poorer parts of the deposit by laying out the main entries so as to follow the rich ore along the fissures. Underground diamond drilling is necessary in some mines to prospect ahead for water channels. These are open fissures that carry so much water that, if broken into carelessly, they make disastrous gushes. Some shafts are pretty wet, making 1300 to 1500 gal. of water a minute. The usual output from each shaft is about 300 tons a day. This output may be greatly exceeded, however, by the use of electric haulage so as to cover a large area from one opening. Ventilation may be secured by drilling large churn-drill holes from the surface.

[1] In some of the mines compressed air locomotives are used, apparently to advantage.

The most economical power equipment used in the district is at the plant of the St. Louis Smelting and Refining Company. Here a central steam plant operates a compressor and an electric generating plant. The mill, hoists, and pumps are operated by electricity. Electric trams are also used to haul the ore from various shafts to the mill.

The cost of mining, hoisting, and pumping is from $1 to $1.50 per ton. To this may be added 10 cents a ton for drill prospecting, and about 10 cents a ton for hauling the ore to the mill. The total cost of ore is therefore, from $1.20 to $1.70 at the mill.

The Problem of Milling the Ores.—The milling[1] practice is now pretty well established. The ore is ground to 9 mm. Everything smaller than 9 mm. is screened out as soon as the ore passes the crusher. When crushed, the ore is screened to various sizes, from 9 to 2 mm., and this product jigged. The tailings from the coarser jigs are all re-ground. The material below 2 mm. is classified and treated on Wilfley tables, as are also the re-ground tailings. Middlings from the tables are also re-ground in Huntington mills and treated on Frue vanners.

The cost of milling in a 1000-ton plant is from 30 to 75 cents per ton. The cost of a concentrating mill, together with a power plant for the mines, may be estimated at $500,000 for 1000 tons capacity. The new plant built by the Federal Lead Company handles about 2400 tons a day. It is built of steel and concrete, has a large air-compressing and electric plant, and elaborate crushing and sampling arrangements. It cost $900,000.

The Problem of Smelting the Ores.—Smelting may be considered either on a custom or an operating basis. The ore leaves the mill in the shape of a concentrate carrying 70 per cent. lead and 5 per cent. moisture. Freight to East St. Louis is about $1.50 per dry ton. This ore may be sold to custom smelters, who will pay for 90 per cent. of the lead at current quotations, and charge from $6 to $8 per ton smelting charges. On this basis, the cost of freight and treatment figures as follows:

	Lead, 4 cents	Lead, 5 cents	Lead, 6 cents
Freight	$1.50	$1.50	$1.50
Treatment say	7.00	7.00	7.00
Deduction 10 per cent., 140 lb	5.60	7.00	8.40
Total	$14.10	$15.50	$16.90

On an operating basis the cost is about $6 per ton, and the loss, with the best practice, 3 per cent.:

[1] Since this was written a considerable change has occurred through the extensive use of Hancock jigs.

	Lead, 4 cents	Lead, 5 cents	Lead, 6 cents
Freight and treatment	$7.50	$7.50	$7.50
Deductions, 42 lb. lead	1.68	2.10	2.52
Total	$9.18	$9.60	$10.02

On average prices there would be a saving of about $5.50 per ton of concentrates in operating a smelter. But it must be remembered that the above costs could only be secured by a plant handling a considerable tonnage, say 3000 to 4000 tons a month.

Let us now consider the cost of the entire operation with due regard to both capital and operating charges. In the utter lack of any official statements of the companies operating in the Flat River district I shall have to make an estimate of my own, with due apologies to the secretive persons who control the mines for rashly guessing at their secrets, and to the public for any inaccuracies.

The companies operating in the district are the following:

	Mill capacity	Shafts operated 1908	Dividends
Desloge Lead Co	800 tons per day	3	Not stated
St. Joe Lead Co	2,700 tons per day	8	$6,308,357
Doe Run Lead Co	800 tons per day	4	1,859,893
St. Louis Smelting & Refining Co	1,500 tons per day	4	Not stated
Federal Lead Co	3,000 tons per day	6	Not stated
Five companies	8,800 tons per day	25	

Total output 1908 estimated at 100,000 tons pig lead. If we call this an average output and figure that the mills ran 300 days a year, we get a total of 2,640,000 tons and an average yield of less than 4 per cent. I believe that this is an overestimate for tonnage and an underestimate for yield for this particular year, but not for the long run. I shall base my calculations on the performance of this district on a yield of 4 per cent. refined lead, at a price of 4½ cents per pound. I shall exclude from my calculations, as usual, the money paid for mining land on the theory that that is a part of the profit won from the industry. I shall proceed to compute the capital invested in the industry and figure the use of it as an integral part of the operating cost.

Capital in Exploration of Lands.—This must amount to about $2,500-000. The greater part of this has been spent by the St. Joe and Doe Run lead companies, with the Federal Lead Company (including the Central)

a close third. It is probable that the ore in sight is sufficient for about seven years.

Capital in Shafts and Mining Plants.—This I estimate at $2,100,000, being $60,000 each for the twenty-five shafts in operation and for ten other shafts discarded or not operating.

Capital in Milling Plants and Power.—I estimate this at $4,400,000, being $3,400,000 for plants in use, and $1,000,000 for discarded plants, experiments, and failures.

Capital in transportation equipment from mines to mills, but not including railroads leading out of the district, may be estimated very roughly at $1,500,000.

Capital in Smelting Plants.—Including some capacity for smelting outside ores, this amounts to some $2,500,000, including workmen's houses, lands at plant, etc.

Working capital, $2,800,000, being equal to the value of the lead output for three months.

We have then:

Capital in explorations	$2,500,000
Capital in mining plants	2,100,000
Capital in milling plants	4,400,000
Capital in transportation plants	1,500,000
Capital in smelting plants	2,500,000
Working capital	2,800,000
Total	$15,800,000

This is equal to $6 per ton of annual output.

The use of this capital can hardly be calculated at less than 10 per cent. which is sufficient to return the investment in fifteen years with 5 per cent. interest. This calculation does not apply to working capital, however, for that is a quick asset that can always be liquidated. As long as it is in the business, however, it must be considered with 5 per cent. We have then for amortization:

10 per cent. on $13,000,000 risked in business	$1,300,000
5 per cent. on 2,800,000 working capital	140,000
Total annual charge	$1,440,000

This is equal to $14.40 per ton lead and 57.6 cents per ton of ore mined.

The depreciation, or current construction of plants, to take care of changes in method, improvements, removals, etc., should be calculated at 6 per cent. on capital invested. This will equal $780,000, accounting for $7.80 per ton of lead and 31.2 cents per ton crude ore.

We have now covered all the charges incident to the business except the current operating charges. These may be estimated as follows, giving due consideration to varying conditions:

	Per ton, crude	Per ton concentrate yield 65 per cent.	Per ton, pig lead
Mining and hoisting	$1.00 to $1.50	.....	$25.00 to $37.50
Transfer to mills	0.05 to 0.10	.....	1.25 to 2.50
Milling	0.30 to 0.50	.....	7.50 to 12.50
General expense	0.10 to 0.20	.....	2.50 to 5.00
Freight to St. Louis	0.097 to 0.097	$1.60	2.44 to 2.44
Smelting	0.378 to 0.378	6.00	9.23 to 9.23
Total operating	$1.925 to $2.775	.....	$47.88 to $69.17
Add depreciation	0.312 to 0.312	.....	7.80 to 7.80
Dividend cost	$2.237 to $3.087	.....	$55.68 to $76.97
Add amortization	0.576 to `0.576	.....	14.40 to 14.40
	$2.813 to $3.663	.....	$70.08 to $91.37

We find that the mines can pay dividends on what remains above from 2.8 to 3.85 cts. per pound, say for an average 3.3 cents. They can justify their investment at a price of from 3.5 to 4.5 cents, or in round numbers, 4 cents per pound.

This I believe is a fair exhibit of the entire business. I do not pretend that the mines will not show great differences from these figures. The differences I have placed in the operating cost columns are intended to cover, for mining: the difference between a thick and a thin orebody, between dry and wet mines; in milling, the difference in the milling quality of the ores, between simple and elaborate processes, and between small mills and big ones; in general expense, the difference between simple and, elaborate managements. There have been failures in the district. It am striking an average of the successes.

That these figures are not far from the truth may be gathered from the records of the St. Joe Lead Company, which paid more than $5,7005, 000 in dividends and built up its property greatly from an output of about 300,000 tons of lead. This indicates a profit of 0.95 cents per pound. Deducting this from an average price of 4.5 cents we get an average cost of 3.55 cents, less whatever surplus may be credited from surplus in the treasury. The cost, of course, fluctuates with the times. It is always possible during periods of depression to produce more cheaply by cutting wages and curtailing construction and development; on the other hand, in boom times wages are raised and people embark in unusual expenditures for expansion and development. As a matter of fact, lead was sold in St. Louis from the Flat River district, in the years following the panic of 1893, as low as 2.6 cents per pound without loss; but in the boom period of 1906–7 it is doubtful if any of the mines were producing it for less than 4 cents."

In the period since 1908 the changes worth particular note are:

1. A great increase in the production per shaft. It will be noted that in 1908 25 shafts were operating for a total output of 8800 tons a day; now not over 14 shafts are yielding at least 16,000 tons a day. In most cases they are the same shafts. The motive behind this change was the desire more fully to utilize the equipment, which is tantamount to saying in this case that it was not worth while to operate four shafts when one would do just as well. The leader in this improvement was Mr. H. A. Guess, who was for a number of years local manager of the Federal Lead Co.

2. Similarly, to take an example, the mill of the Federal Lead Co. which was designed for an output of 2400 tons a day, was made to treat 5000 tons by virtue of minor changes and adjustments.

It was found that it took no more men to work the machinery twice as hard so that it worked out that the output per man for mining and milling was doubled. This was a signal achievement which is touched on to some extent in other chapters.

3. The introduction of oil flotation has made and is still making important changes in the scheme of milling. It is now possible to recover 90 per cent. of the lead, while with water alone the recovery scarcely reached 80 per cent. on the best ores and probably in some cases fell below 70 per cent. Perhaps the jigs will finally be discarded altogether. At the Bonne Terre mill the ore is now ground at once to 2 millimeters and washed on tables which take out a large part of the clean galena and also reject the coarser and nearly barren sand; the remaining tailings and slimes are then treated by flotation. It is found, by the way, that the limestone of this district cannot be ground as readily in ball or rod mills as many of the silicious ores of the west.

4. The St. Joseph and Doe Run Lead Companies have been consolidated and reorganized. Great economies have been made in the production and use of power, in the distribution of supplies, in the operation of the transportation system and in the process of smelting. This one concern has made an output of as much as 110,000 tons of pig lead a year, and might be called the "Calumet and Hecla" of lead mines.

The total production of lead from this district to the end of 1919 has been approximately 2,650,000 tons, presumably from about 65 to 70 million tons of crude ore. Of this the St. Joseph Lead Co. has contributed 1,460,000 tons and paid about $26,700,000 in dividends. It will be noted that the dividends have averaged almost exactly the same amount as was stated in the first edition, *i.e.*, $19.00 per ton.

St. Joseph Lead Company and Subsidianies
Cost of Operating December, 1914

Production and value	Total	Pounds recovered
Tons ore mined	137,469	
Tons ore milled	133,599	
Lb. wet concentrates	16,568,360	
Lb. pig lead equivalent	10,318,622	
Lb. wet flotation product	995,340	
Lb. pig lead equivalent	407,398	
Lb. wet slime	97,800	
Lb. pig lead equivalent	42,653	
Total pig lead equivalent	10,768,673	78.34
Estimated value at	$389,039.85	
Cost of production		Cost ton
Prospecting	$10,494.45	0.076
Mining	87,843.31	0.639
Ore freights	11,934.56	0.087
Suspension	5,388.75	0.039
Milling	45,945.56	0.334
General and indirect operating	38,927.92	0.284
Depreciation	26,296.55	0.191
Interest	25,868.39	0.188
Discount	13,406.73	0.098
Total cost ore to concentrates	$266,106.22	$1.936
Other costs and incomes		Cost cwt.
Freights (concentrates and pig lead)	$11,237.03	0.1043
Smelting costs	69,662.55	0.6469
Selling costs	1,756.30	0.0163
Total cost of product	$348,762.10	3.2387
Cost per ton smelted about	$7.50	

Total Shifts Worked 64.724. Output per Shift in all Departments, Mining, Railroad and Smelter 2.15 Tons.

CHAPTER XXI

SILVER-LEAD MINING

General remarks on the silver-lead mines of the Cordilleras—Their identical origin—Cœur d'Alene mines—Economic features—Wardner vein—Bunker Hill and Sullivan—Canyon Creek 1908—Later history—Hecla—Hercules—Smelting—Decline of Federal Mining and Smelting—Broken Hill Proprietary—Park City in 1908

General Remarks on the Silver-lead Mines of the Cordilleras.—Idaho and Utah have for two decades yielded about half the lead of the United States. Twenty years ago a mining engineer would have described the respective occurrences as very different; now, by virtue of the generalizations of such geologists as Lindgren, Kemp, and Ransome he is bound to recognize that they originated in a common process. In every case some connection, direct or inferred, may be traced to igneous, generally granitic intrusions. Solutions flowing from enclosed magmas have deposited metallic compounds in the covering rocks into which they escaped and through which they traveled along any available channel. In Utah the rocks which received the deposits thus formed were moderately tilted limestones and quartzites of Paleozoic age, and the outer periphery of certain of the granite masses; in the Cœur d'Alenes the rocks were Algonkian sediments of great thickness thrown into rather sharp folds. In Utah the solutions rising perhaps from the magma through a fissure frequently were able to find pervious beds along which they proceeded great distances, irregularly but persistently depositing ores in long ribbons. Such bodies are almost invariably in limestone beds, but in no case is any bed the invariable or sole locus of deposition. The association of the ores with the limestones is not inherent but accidental. There will be various beds in which ores will be deposited merely in proportion to the extent to which those beds were accessible to the solutions. The only invariable fact is the emergence of the ores from the magmas. Every district shows a group of phenomena essentially equivalent to that of every other district. Practically every metal is found in some proportion. Frequently the same district (Bingham for instance), contains deposits valuable here for copper, there for zinc, elsewhere for lead; somewhere else for silver, gold or manganese; sometimes for several metals at once. Some such deposits are disseminated in large volumes of rock, sometimes chiefly in fault fissures, sometimes in beds, sometimes in or along the walls of dykes, sometimes at the contacts of batholithic masses with various rocks; sometimes within the body

of the batholith, sometimes in the zone of contact metamorphism that surrounds it; sometimes in fresh unaltered rocks far beyond such a zone. The nature of such a deposit is not governed by the rock or the fissure in which it occurs, but by the volume and energy of the mineralizing flow and the distance from the source of that flow. Apparently the deposition of certain minerals was determined by the progressive loss of temperature by the emerging solutions. A little reflection on this point will enable one to see that during the process of mineralization the factors governing such changes might vary greatly: fresh fissures might be opened, and old ones closed, by earth movements such as must invariably take place around either an emerging or a cooling magma; the batholithic action itself might be renewed, or be intermittent, and new supplies of magmatic waters might be given off with varying energy and temperature from time to time. Thus we may see that almost at the same place deposits with considerably different characters may be formed in different phases of the same mineralization. One deposit sometimes carries a good deal of copper as well as lead and silver, while another a few hundred yards away will carry the lead and silver but no copper. One may imagine that the first might have been formed by a hot gush of solution emerging from the magma at an earlier or later stage than the second, or the latter might be fed from a fissure which tapped the magma at a greater distance.

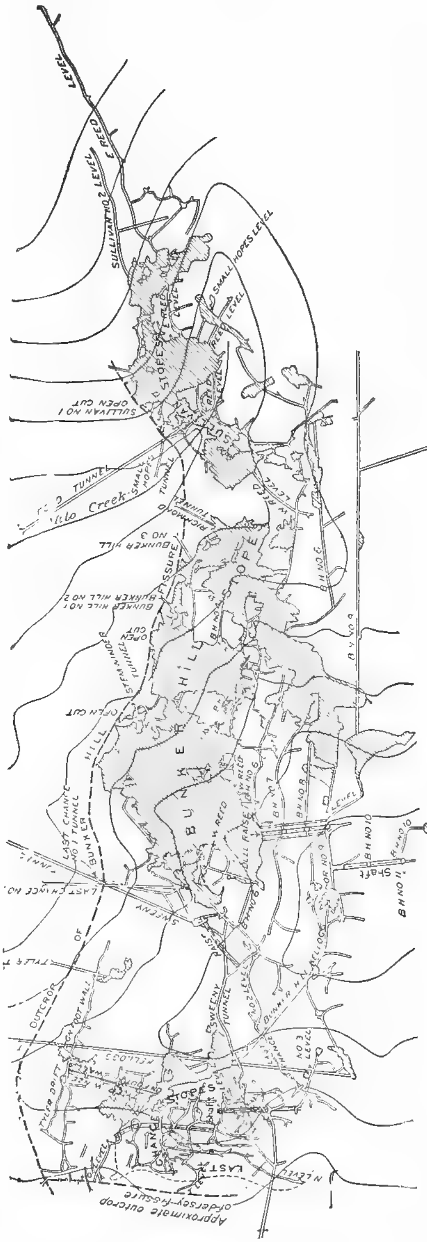


FIG. 9.—Orebodies along Wardner Vein.

In general silver-lead deposits are not found within, or in immediate contact with, the batholithic masses, but copper deposits frequently, indeed generally, are. In a silver-lead mine zinc frequently increases markedly in proportion to lead at greater depths. From such facts the inference is made that copper is probably deposited at higher temperatures than zinc; zinc than lead, lead than silver, etc., but while this general succession is recognizable the detail will be frequently confused in a manner explicable by the preceding paragraph.

In various parts of the Coeur d'Alene district there are mines of copper, zinc and silver, lead and silver, silver only, and gold only. The zonal occurrence seems to hold good pretty accurately except for the copper which is confined to the eastern part of the district several miles from the exposed granitic stock. But who knows that there are not *unexposed* granitic masses beneath these copper veins?

The simplest relationship of the silver lead veins to the batholith may be seen, or figured out, in the Canyon Creek part of the district. The granite appears on the ridge between Canyon Creek and Nine Mile Creek. The granite stock seems to have nearly a perpendicular contact with the sedimentaries on its east side, and cuts across some folds indiscriminately. Beginning at the north there are the following principal lodes; Hercules, Tiger-Poorman, Hecla, Standard-Mammoth, Frisco, Morning and Gold Hunter. All these lodes show the following peculiarities.

1. They lie in unmetamorphosed sedimentaries of great thickness.
2. They occur in a zone which fringes the granitic stock.
3. Their general course is nearly at right angles to the major axis of the stock.
4. The deposition is entirely in fissures and does not spread out along beds.
5. The ores are found in greatest abundance where the veins traverse quartzites (Burke and Revett) rather than in the dense clay slates (Pritchard).
6. There is a decided tendency for zinc to increase in depth.
7. There is reason to believe that the top of the ore shoots, as originally deposited, corresponds to the present altitude of about 6000 ft. above sea level. The Tiger-Poorman and Helena-Frisco veins showed strong outcrops of ore near the bottom of the Canyon Creek valley at elevations between 3000 and 4000 feet. The Hercules, Mammoth and Morning showed extremely meager outcrops of ore at elevations between 5000 and 6000 ft. It is doubtful if the Hecla lode had any outcrop of ore. The crest or summit of the ore-shoot seems to lie below the surface at an elevation of about 4500 ft. It may be noted that this ore shoot is further from the granite stock than any of the others. An apparent exception to this is the case of the Morning and Gold Hunter lodes; but acid dykes

are found near those mines, a fact that leads to the suspicion that the granite mass, or an off-shoot from it, is not far below. In confirmation of this suspicion is the fact that the Morning and Gold Hunter carry a great deal of zinc. However, a branch vein on the Hecla property known as the Ore-or-no-go, which may be older than the real Hecla lode, carries a good deal of zinc quite near the surface.

8. There is reason to believe that the vertical range of commercial silver-lead deposition in any one lode is limited to about 4,000 ft. Moreover it is entirely conceivable that all the principal veins have had ore over about that range. The Helena Frisco and Tiger-Poorman lodes which became unprofitable at depths of less than 2,000 feet below their present outcrop may have, indeed probably, once extended 2,000 ft. above that outcrop.

The Wardner part of the district is 20 miles away. How far all these generalizations may apply to it is hard to say. No granitic mass is exposed. But the mineralization is identical and the habit of the veins identical. The great practical question is the vertical range of the ores, which we may suppose will be different, certainly as to present altitude. If the expectation of life of the Bunker Hill lode is limited to a vertical range of 4000 feet it is still uncertain what the life will be because how far it once extended above the outcrop cannot be known.

In a general way the expectation of future output from veins now being worked in the Cœur d'Alene field thus seems to be limited by facts proven by experience, but to draw the conclusion that profitable operations will have ceased at any date that can now be fixed is not warranted. One may say this confidently on the basis of experience. Such an extensive field may be counted on for fresh discoveries, if not in the way of new veins at least in the way of branches, or extensions, or overlooked portions, of old ones. But that is hardly all. It seems legitimate to draw, from the generalizations of ore occurrence given above, the inference of two possibilities in which might lie the discovery of brand new silver-lead mines.

1. Explorations within the zone of known productive lodes at approximately the level of greatest productivity. About the only space I know of in the Canyon Creek field where this exploration is not covered by tunnels already driven is that between the Morning and Hecla mines, where the surface is higher than the level reached by known ore-shoots. A tunnel driven across this space at an elevation of about 3000 feet might cut veins which do not reach the surface. Some mineralization in subsidiary cracks parallel to the principal veins has been found as far as openings have been made.

2. In the region between Nine Mile and Wardner some of the veins which contain only silver where exposed might carry silver-lead at a

lower horizon. This is a bald speculation based on the zonal theory of ore deposition.

The external factors which affect mining in the Cœur d'Alene are the most favorable of the whole Rocky Mountain region. The altitude is moderate, the climate mild; timber and water power are abundant and cheap. Transportation to consuming centers is, however, expensive, and wages are high. Labor is efficient and abundant. The mines are generally deep, measured from the surface, but the configuration of the country has permitted their attack by adit levels; so that most of the ore has not needed hoisting from great depths, and pumping operations have generally been inexpensive.

The internal factors are favorable. The veins are typical fissures. The ore is galena, which seems to be a metasomatic replacement of pre-existing veins of iron carbonate. Ransome believes that the Burke and Revett quartzites, flaggy, evenly bedded, light-colored rock about 3,000 ft. thick, contain nearly all the payable ore, although veins are found traversing an immense mass of slates and quartzites of presumable Algonkian age, some over and some under the productive formations. The whole sedimentary series is estimated to have a thickness of 13,000 ft.[1]

The ore shoots are persistent and profound, with a thickness varying from 8 to 100 ft., and a length varying from 100 to 1000 ft. normal to the plunging axis. Single bodies have produced 5,000,000 tons or more. The ore in the main has to be concentrated. The proportion shipped to the smelters varies from a quarter to a tenth of the amount mined. Of the proportion shipped a considerable amount is picked out by hand either underground or at the mill, the lower grades being concentrated. In addition to the sorting of first-class ore, there is a still larger sorting of waste in the stopes. In many cases it is necessary for safety to fill the stopes, and in all cases it is economical to reject waste. The various mines differ greatly in the amount of sorting and filling done. Several have run for years without shipping any first-class ore and wihout sorting any waste in the stopes, everything mined being sent to the concentrator. On the other hand, one prominent mine, the Hercules, ran several years without a mill, shipping only first-class ore.

[1] Perhaps all the statements in these two paragraphs need some modification through the developments of the past ten years. It is probable that neither the wages nor the average capability of the miners is any longer comparatively high. Nor are many of the mines accessible wholly by tunnels. The veins are the same as ever but they are being worked at levels 1000 or 1500 feet deeper than ten years ago.

It is now quite clear that while the rocks in which the ore is found is of Algonkian age, the veins are post-Cretaceous. The granite batholith from which the veins spring and which they surround is no doubt part of the same movement that produced the great batholiths of Butte and of Central Idaho as well as many smaller ones in this region. The ore deposits therefore belong to the Eocene "revolution" like those of Butte, Cripple Creek, Clifton, Ariz , and many others.

Producing Mines.—The mines may conveniently be divided into two groups: the Wardner and the Canyon Creek. In Wardner there is only one important mine: the Bunker Hill & Sullivan.

The Wardner district used to be described as one vein, but that idea has been proved long ago to be a mistaken one. There are not only a number of different veins but two or three *systems* of veins of different ages. It can hardly be said that the mineralization is greatly different in the various systems but I suppose one familiar with the ores might tell them apart.

The largest ore bodies are along the Bunker Hill lode, which is a mineralized fault of considerable displacement. One group of such ore bodies, perhaps better described as one large shoot, occurs on the footwall side of the main fissure, a second large group, not quite so persistent as the first, on the hanging wall side. It used to be supposed, by the way, that there was one universal "footwall" fissure for the whole district; but it appears that the eastern part of this supposed "footwall" is merely an older vein which is cut and displaced a considerable distance by the Bunker Hill fault. Another set of veins called the Jersey system is also cut by this fault, almost at right angles. Some of these veins are highly productive and valuable.

It is perhaps safe to conclude that all the mineralization came from the same source but that the location of deposition was changed two or three times by the opening of fresh fissures. In this respect it is very much like the Butte district.

The mining is done almost wholly by the filling method. Whether square sets are put in first and then filled, or whether the stopes are filled without timbering, depends on the firmness of the ground. This varies in different parts of the mines. In nearly all cases enough waste for the filling can be sorted out of the vein-stuff itself.

The Bunker Hill mine in twenty-two years up to June 1, 1908, had produced as shown in the following table:

	1908	22 years
Average yield per ton crude ore, lead per cent	9.8	9.68
Ounces silver	3.84	3.82
Average contents of shipping product, lead per cent	43.17	51.45
Silver, ounces	16.58	20.31

It will be observed that while the yield of the crude ore per ton is almost exactly the same as for the entire period the grade of the shipping product has dropped about 15 per cent. No significance attaches to this except that in recent years a considerable tonnage of low-grade concentrates containing less than 10 per cent. lead and a high percentage of iron has been shipped on account of its favorable fluxing qualities. In earlier periods no such ore was shipped. Of course with the present grade of shipping ore the cost per ton will be considerably different for smelting charges than with the higher grade of past shipments.

BUNKER HILL & SULLIVAN, WARDNER, IDAHO

DATA PER TON OF ALL ORE MINED, BOTH SHIPPING AND CONCENTRATING

	May, 1886, to May, 1892, inclusive 6 yr. 1 mo.	June, 1892, to May, 1900, inclusive 8 yr.	June, 1900, to May, 1907, inclusive 7 yr.	June, 1907, to Mch., 1908, inclusive 10 mo.	April, 1908 1 mo.	May, 1886, to April, 1908, inclusive 22 yr.	Future expectations
Assay values, lead, lb.	295.56	220.90	217.34	229.50	214.06	225.60	220.00
Assay values, silver, oz.	5.99	5.23	4.61	4.76	4.26	4.92	4.82
Recovered values, lead, lb.	274.60	178.30	195.10	196.20	176.70	193.60	187.00
Recovered values, silver, oz.	5.96	3.76	3.67	3.84	3.45	3.82	3.86
Average New York daily market prices, lead, dollars, per 100 lb.	4.33	3.65	4.615	4.515	3.993	4.18	4.18
Average New York daily market prices, silver, cents, per oz.	97.37	66.54	59.64	61.45	54.50	72.63	50.00
Average New York market prices when products sold, lead, dollars, per 100 lb.	4.36	3.72	4.788	4.451	3.993	4.427	4.20
Average New York market prices when products sold, silver, cents, per oz.	95.94	65.96	61.18	61.46	54.50	65.18	50.00
Gross assay value of ore, dollars	18.63	11.67	13.23	13.35	10.868	13.19	11.65
Tailing loss in concentrating, dollars	0.94	2.56	1.64	2.08	1.932	2.13	1.87
Net value of ore, dollars	17.69	9.11	11.59	11.27	8.936	11.06	9.78
Cost of mining, dollars	2.319	2.277	1.752	1.568	1.523	1.930	1.50
Cost of tramming, dollars	0.114	0.103	0.079	0.084	0.077	0.088	0.07
Cost of concentrating, dollars	0.623	0.351	0.252	0.423	0.372	0.315	0.35
Cost of general expenses, dollars	0.947	0.360	0.261	0.352	0.302	0.332	0.28
Total operating costs, dollars	4.003	3.091	2.344	2.427	2.274	2.665	2.20
Cost of betterments, etc., dollars	3.401	1.019	0.501	0.533	0.437	0.800	0.30
Cost of shipping, smelting, and marketing, dollars (including loss in smelting)	8.95	3.99	5.47	5.45	3.940	5.16	3.50
Total costs of every kind, dollars	16.354	8.100	8.315	8.410	6.651	8.625	6.00
Mining profit, dollars	1.336	1.01	3.275	2.86	2.285	2.435	3.78
Other earnings, dollars	none	0.124	0.831	0.090	0.043	0.509	0.04
Total profits, dollars	1.336	1.134	4.106	2.95	2.328	2.944	3.82
Dividends, dollars	0.884	0.672	3.929	4.518	2.377	2.804	3.00
Cash and cash assets, dollars	0.452	0.462	0.177	[1] *1.568*	[1] *0.049*	0.140	

The operating details of the Bunker Hill and Sullivan were given in great detail in the first edition. Although no abrupt changes in costs

Miscellaneous Data

Shipping, smelting, and marketing, including loss in smelting, per ton of product shipped, dollars	42.69	25.02	27.95	23.05	20.88	27.40	19.25
Total tons of ore mined	169,752	1,116,212	2,002,146	272,220	31,550	3,591,880	
Average number of tons per month	2,326	11,627	23,835	27,222	31,550	13,606	40,000
Total tons of shipping ore and concentrate	35,616	177,930	391,953	64,409	5,950	675,858	
Average number of tons per month	488	1,853	4,666	6,441	5,950	2,560	7,273
Total contents of all products shipped: tons lead	23,310	99,538	195,378	26,712	2,788	347,726	
Total contents of all products shipped: ounces silver	1,011,527	4,199,359	7,35[illegible],755	1,045,892	108,941	13,724,474	
Average output per month: tons lead[1]	320	1,037	2,32[illegible]	2,671	2,788	1,317	3,740
Average output per month: ounces silver	13,952	43,743	87,604	104,58[illegible]	108,941	51,987	154,400
Number of tons of ore mined per one ton of product shipped	4.77	6.27	5.11	4.23	5.30	5.31	5.50
Value of silver recovered per pound of lead marketed, cents	2.083	1.391	1.150	1.203	1.064	1.286	1.032
Number of pounds of lead contained in ore per ounce of silver contained in ore	49.35	42.22	47.11	48.19	50.28	45.95	45.64
Number of pounds of lead recovered per ounce of silver recovered	46.07	47.42	53.16	51.09	51.22	50.68	48.45
Percentage of contents of both shipping and concentrating ore recovered for shipment: lead	92.89	81.16	89.87	81.16	82.44	85.81	85.00
Percentage of contents of both shipping and concentrating ore recovered for shipment: silver	99.49	71.89	79.61	80.67	80.98	77.64	80.00

[1] Other resources than profit drawn upon in payment of dividend.

took place until 1917 the scale of output gradually increased so that the details for 1908 no longer seem to have enough interest to make it worth while to retain them. In their place I now insert more recent statistics.

KELLOGG OPERATIONS

Mining 1917 and 1916

The mine was in operation for the full period of twelve months and produced 492,617 tons of concentrating ore and 413 tons from exploration at a cost of $1,176,074.56, as follows:

Details of labor and supplies	Total for 1917	Average cost per ton for the year	1916
Superintendent and Foremen	$ 11,101.50	$0.023	$0.023
Shift Bosses	19,571.72	0.040	0.042
Machinemen	66,802.72	0.136	0.166
Chuck Tenders	24,245.07	0.049	0.079
Miners	89,480.25	0.181	0.191
Shovelers	178,292.73	0.362	0.354
Carmen and Trammen	21,144.68	0.043	0.034
Motormen	10,565.42	0.021	0.024
Timbermen and Carpenters	88,839.15	0.180	0.151
Hoistment and Skipmen	16,783.42	0.034	0.037
Pumpmen	5,503.80	0.011	0.010
Pipemen	1,559.31	0.003	0.003
Nippers	6,342.00	0.013	0.010
Supplymen	21,936.17	0.044	0.042
Repairmen	4,966.04	0.010	0.009
Timekeeper	2,096.50	0.004	0.004
Contractors	5,126.70	0.011	0.003
Concretemen	245.25	0.001	0.008
Miscellaneous	1,242.72	0.002	0.003
Powder	46,753.60	0.095	0.108
Fuse and Caps	9,152.18	0.019	0.020
Illuminants	3,233.83	0.007	0.008
Lubricants	1,086.02	0.002	0.002
Timber and Lagging	113,361.93	0.230	0.227
Miscellansous Supplies	52,565.41	0.106	0.102
Cement	92.65	.....	0.006
Machine Shop Repairs	20,094.06	0.041	0 041
Electrical Repairs	7,931.02	0.016	0.017
Building Repairs	3,962.99	0.008	0.008
Tool Shop Repairs	7,039.40	0.014	0.015
Electric Power	14,172.05	0.029	0.025
Compressed Air	44,065.20	0.090	0.086
Electric Light	153.60	.....	......
Heating	5,910.19	0.012	0.014
Surveying	7,435.85	0.015	0.018
Train Service	6,899.35	0.014	0.015
Teaming	155.52	.....	.....
Tramming Ore	25,304.80	0.051	0.052
Tramming Men into Mine	1,357.71	0.003	0.003
Tramming Supplies into Mine	2,102.75	0.004	0.004
Contingent Expense	26,076.52	0.053	0.046
Legal Services	2,601.50	0.005	0.032
Depreciation	41,106.84	0.084	0.085
Administrative Expense	43,629.93	0.089	0.082
Free Light, Water and Rent	43,629.93	0.089	0.082
Taxes and Insurance	84,849.26	0.017	0.123
Fire Protection	223.56	.....	.....
Total Normal Expense	$1,147,851.07	$2.328	$2.333
Litigation and Other Extraordinary Expense	28,223.49	0.057	0.031
Total	$1,176,074.56	$2.385	$2.364

The above mining costs have been subdivided under the following heads, viz.: Exploration, Stoping, Tramming, Hoisting, Pumping and General Mine Expense, the details of which are below reproduced.

		Total cost	
Exploration	1524 feet	$30,579	$20.06 per foot
Stoping	493,030 tons	779,589	1.58 per ton
Tramming	493,030 tons	28,765	0.06 per ton
Hoisting	448,843 tons	25,253	0.06 per ton
Pumping	448,843 tons	20,734	0.05 per ton
General expense	493,030 tons	291,150	0.59 per ton

The total of all these items is the mining cost given above with details of labor and supplies.

Concentrating	493,030 tons	$295,964	$0.66 per ton
Shipping	102,911 "	23,402	.23 " "
Grand total mining and milling		1,495,436	$3.03 per ton

MILLING DATA

Days ran	355.70
Tons milled	493,030
Assay feed, per cent. lead	10.6496
Assay feed, ounces silver	4.317
Contents feed, tons lead	52,506.318
Tons concentrates	103,981.84
Average assay concentrates, per cent. lead	45.1967
Average assay concentrates, ounces silver	16.2794
Contents concentrates, tons lead	46,996.449
Per cent. extraction lead	89.51
Contents feed, ounces silver	2,128,436.87
Contenst concentrates, ounces silver	1,692,765.17
Per cent. extraction silver	79.54
Value feed	$10,878,283.04
Value concentrates	$4,943,782.37
Economic extraction, per cent	45.44
Tons milled per 24 hours	1,386.08
Tons concentrates produced per 24 hours	292.33
Tons lead produced per 24 hours	132.12
Cost per ton milled	$0.600
Cost per ton concentrates	$2.846

SEGREGATED COSTS FOR 1917 [EXPLORATION, ETC.]

GENERAL COST STATEMENT

1916

	Per ton concentrates produced	
To production costs		
Mining—475,784 tons mined	$14.74	$1,124,773.10
Milling—475,784 tons milled	3.75	286,069.71
Shipping expense—75,963.96 tons concentrates shipped	0.25	19,064.92
Smelters' Charge		
Freight and treatment and lead and silver discounts (on ore shipped)	38.74	2,955,221.15
To south mill expense	0.14	10,644.12
To north mill expense	0.14	10,728.60
To north mill experimental	0.39	29,420.75
To mine examinations		300.00
To Bunker Hill Smelter expense at San Francisco	0.02	1,255.23
Total operating costs	$58.17	$4,437,477.58

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HISTORICAL SUMMARY OF OPERATIONS

Year and month (Dates inclusive)	Total ore mined	Total gross assay value of ore recovered	Net smelter returns	Operating profit	Profit from other sources	Dividends paid
May, 1886 to July, 1887	26,855	$637,530.40	$297,800.01			
Aug., 1887 to Dec., 1888	79,263	1,654,900.69	772,114.90	$458,775.78		
June, 1888 to May, 1889	37,784	734,968.02	332,014.30	171,973.39		
June, 1889 to May, 1890	No ore mined or treated		....	....	....	$150,000
June, 1890 to May, 1891	17,092	158,494.77	76,961.97	35,805.37		
June, 1891 to May, 1892	52,114	766,221.80	434,192.35	233,047.08		
June, 1892 to May, 1893	105,287	1,226,167.55	683,786.40	256,352.90		
June, 1893 to May, 1894	99,657	1,158,408.08	586,358.32	286,110.33	....	60,000
June, 1894 to May, 1895	71,084	562,500.68	267,527.97	73,147.72	....	15,000
June, 1895 to May, 1896	142,976	897,295.12	535,527.91	160,467.38	....	36,000
June, 1896 to May, 1897	171,359	1,122,930.42	665,065.14	170,428.74	....	9,000
June, 1897 to May, 1898	187,243	1,566,949.42	945,024.91	474,346.85	....	183,000
June, 1898 to May, 1899	178,568	1,519,244.54	917,168.58	399,956.17	$27,163.06	246,000
June, 1899 to May, 1900	160,035	1,862,729.42	1,169,766.69	614,123.90	17,108.34	201,000
June, 1900 to May, 1901	227,308	1,663,522.33	978,857.30	318,431.72	22,996.80	252,000
June, 1901 to May, 1902	281,590	1,815,798.68	1,051,686.28	337,696.34	18,474.12	240,000
June, 1902 to May, 1903	260,500	1,623,290.51	897,728.04	211,781.84	32,143.61	45,000
June, 1903 to May, 1904	285,357	1,964,777.82	1,161,765.58	591,477.32	36,205.09	309,000
June, 1904 to May, 1905	320,056	3,643,401.12	2,077,993.67	1,497,122.25	182,653.57	1,200,000
June, 1905 to May, 1906	347,350	4,784,428.40	2,981,833.60	2,375,263.04	1,465,402.39	3,480,000
June, 1906 to May, 1907	336,630	5,011,807.10	3,293,157.00	2,627,778.20	57,383.70	2,340,000
June, 1907 to May, 1908	335,070	3,391,426.10	2,039,771.70	1,308,751.67	26,841.55	1,380,000
June, 1908 to May, 1909	344,470	3,199,975.90	1,856,932.70	1,095,558.68	30,917.52	825,000
June, 1909 to May, 1910	377,530	3,307,825.80	1,989,529.30	1,200,551.81	42,530.66	668,100
June, 1910 to May, 1911	438,290	3,307,393.69	2,051,664.77	1,110,314.73	34,733.54	1,062,750
June, 1911 to Dec., 1912	702,520	5,396,915.51	3,416,684.55	1,738,403.69	80,804.60	1,209,900
Year 1913	436,060	3,890,139.16	2,329,888.27	1,119,960.51	118,433.37	817,500
Year 1914	440,819	3,362,498.96	2,100,136.70	949,986.80	160,257.87	981,000
Year 1915	455,205	4,177,819.20	2,912,860.16	1,264,959.04	603,637.16	1,062,750
Year 1916	475,784	6,253,048.40	3,297,827.25	1,867,791.97	520,282.26	1,716,750
Year 1917	493,030	9,584,963.40	....	....	240,443.13*	2,043,750
Totals	7,886,886	$80,247,372.99	$46,975,408.69	$26,261,032.15	$3,718,412.34	$20,533,500

* After deducting Income and Excess Profits Taxes not distributed in Operating Costs.

It appears further that the costs incurred on the ground, *i.e.*, omitting smelting costs and losses were $3.13 per ton crude ore mined and $19.58 per ton of concentrates. These costs were not increased in the following year which is surprising. In 1917 the cost on the ground was per ton crude $3.16 and per ton concentrates 14.96. The decline in the cost of concentrates was due no doubt to the increased yield.

This summary shows that on the average the net smelting costs and deductions have been about 43 per cent. of the total value recovered at the mine: that the operating profit is about 55 per cent. of the net smelter returns and 32 per cent. of the gross value; that out of 30,000,000 obtained from operating and other profits only $20,500,000 was paid in dividend—68 per cent. The remaining profits have been absorbed of course in purchase of property, construction of plants and in working capital. We may summarize the whole history as follows:

7,886,886 tons cost for operating	$20,700,000 =	$2.62 per ton
for capital	9,500,000 =	1.20 per ton
Total for 31 years		$3.82 per ton

The capital requirements have been increased considerably since 1915 by the construction of a smeltery at Kellogg. This means a good deal additional for working capital, the total of which stood at the end of 1917 at about $3,000,000 net.

The mine is thought to be good for a long life, although only 3,457,000 tons or about 7 years life is reported in sight. The mine is 2600 feet deep vertically and perhaps 4000 feet on the slope; but the ore has not changed its character appreciably from top to bottom.

Canyon Creek.—The Canyon Creek mines differ from the Wardner mines only in the shape of the orebodies. The dip is not far from vertical; the ore shoots are much longer, thinner, and more regular. Wages

Operations of the Federal Mining and Smelting Company for Three Years Ending 1908

Total tons mined and milled	2,428,112
Tons lead in shipping product	166,912
Ounces silver in shipping product	10,300,049
Percentage lead	6.87
Ounces silver per ton	4.24
Value of product	$24,310,441
Smelting, refining, and deductions	10,514,773
Net value to mining company	13,795.668
Profits reported	6,160,247
Total cost	7,635,421
Cost per ton, mining and milling crude ores	3.14
Cost per ton, concentrates shipped	22.03
Smelting, refining, and marketing concentrates	30.35

average 46 cents an hour (in 1908), 4 cents higher than in Wardner. Details of cost are not given.

It will be seen that these figures indicate conditions similar to those of Wardner. Further elaboration of detail seems unnecessary. The costs are higher than at the Bunker Hill, but the difference at the mine is to be explained by the factors, (1) higher wages, (2) a greater amount of hoisting and pumping, (3) a charge for railroad transportation from mines to mills, (4) a greater number of power and mining plants to maintain, and a higher power cost. In each case these factors are inherent to the problem and cannot be removed.

The cost of mining and milling, of construction, of freight and treatment; and the value of the ore to the mines, free from smelter deductions for a period of five years during which the average price of lead in New York was 4.6 cents and of silver 59.2 cents, are given for a number of properties in accompanying tables:

Cost and Value of Ore per Ton at Six Mines for Five Years
(New York prices; lead, 4.6c; silver, 59.2c.) 1908.

	Tons	Cost mining and milling	Construction	Total	Freight and treatment	Total cost to mine	Value to mine	Profit
Hecla	402,000	$3.43	$0.47	$3.90	$2.56	$6.46	$9.57	$3.11
Standard	1,244,571	2.91	0.15	3.06	2.37	5.43	7.29	1.86
Tiger-Poorman	488,675	2.94	0.10	3.04	1.71	4.75	4.99	0.24
Morning	924,416	1.96	0.15	1.22	2.51	4.62	5.42	0.80
Last chance	670,164	2.66	0.08	2.74	2.99	5.73	8.19	2.46
Total and averages	3,729,826	.....	.....	$2.90	$2.43	$5.33	$6.93	$1.60

Estimated Average Value of Chief Items

Smelter deductions	$1.50
Loss in milling, 20 per cent. (In some of these mines where no first-class ore is shipped, the loss is probably greater; where a good deal is picked out the loss is probably less)	2.11
Gross value of ore before milling, at N. Y. quotations	10.54
Per cent. lead, before milling	8.66
Ounces silver per ton, before milling	4.33
Cost to mine per pound lead at New York	3.54 cents
Cost to mine per ounce silver at New York	46 cents
Cost of lead in New York (actual cost)	3.36 cents
Cost of silver in New York (actual cost)	43.5 cents

If these mines were all owned by the American Smelting and Refining

Company, and the cost of the whole process from mine to market were to be given, it would probably be something as follows:

Total value recovered per ton	$8.00
Cost of mining, milling, and construction	2.90
Cost of smelting, refining, and marketing	3.20
Profit per ton	1.90

These were the facts in 1909. Since that time the Standard-Mammoth, Tiger-Poorman, and Last Chance (Wardener) mines have been worked out and abandoned; as well as the Success mine which was not mentioned in the first edition but which was a resuscitated old mine that ran successfully for a number of years. Other mines like the Hecla and Hercules have increased their output enough to make up for the decline of others, and one new vein, the Interstate-Callahan, which produced heavily for a while, was discovered. The last was principally a zinc mine but it produced some lead and a good deal of silver.

The Hecla mine has improved steadily at least to the depth of 1600 feet below the level of Canyon Creek. In all probability the deposits will not weaken suddenly with increasing depth, but very likely are approximately lens shaped so that if the 1600-ft. level is that at which the volume of ore is greatest it seems reasonable to suppose that as much ore might be obtained from below it as above it. Whether the 1600-foot level is actually the best in the mine or not is beyond my knowledge; but, assuming it and applying the above theory, we get the following:

Amount of ore mined to end of 1918	2,400,000 tons
Ore in sight above 1600 ft. level end of 1918	1,500,000
Total accounted for to 1600 ft. level	3,900,000
Add for presumed lower half	3,900,000
Total ultimate production	7,800,000
Deduct production to date	2,400,000
Future expectation	5,400,000
Rate of mining, 1917 and 1918 per year	375,000 tons
Length of line at that rate, less than	15 years

It is generally believed that the portion of the Algonkian series of rocks known as the "Burke" and "Revett" quartzites is that in which the silver-lead veins are particularly productive. Some mines in the district are thought to have played out when the workings reached the underlying "Pritchard" slate. If this theory is correct the Hecla mine may be expected to go to a great depth, for the Burke quartzite is dipping nearly vertically into what is probably a very deep fold across which the vein cuts nearly at right angles.

Following is a table showing the progress of this concern in the past few years;

RECORD OF HELCA MINING CO. FOR SIX YEARS—
COMBINED HECLA AND ORE-OR-NO-GO

	1913	1914	1915	1916	1917	1918
Tons mined	141,930	123,857	146,675	250,559	374,213	379,703
Tons shipped	19,937	20,052	26,214	40,832	45,517	52,894
Pounds lead produced	18,832,534	18,957,823	24,917,867	40,217,573	44,363,559	51,635,676
Ounces silver produced	507,236	509,200	692,444	1,195,841	1,366,960	1,599,062
Pounds zinc produced	....	....	....	....	507,888	433,341
Pounds lead per ton	945	945	951	985	975	971
Ounces silver per ton	35.40	25.40	26.40	29.30	30.00	30.06
Pounds zinc per ton[1]	....	....	....	....	153	90.00
Average lead quotation	$4.364	$3.866	$4.866	$6.936	$8.474	$7.347
Average silver quotation	0.595	0.550	0.504	0.673	0.829	0.980
Average zinc quotation	....	....	....	....	$9.060	7.640
Dividends	$320,000.00	$220,000.00	$565,000.00	$1,550,000.00	$1,600,000.00	$350,000.00

[1] Ore-Or-No-Go Tonnage Shipping Product.

The cost of operating the Hecla mine in 1916 and in 1918 was as follows, per ton raised;

	1916	1918
Mining	$1.901	$2.912
Development	0.193	0.369
Ore sorting	0.163	0.228
Permanent improvements	0.507	0.807
Miscellaneous (Gen. expense, etc)	0.250	
Total for mining	3.024	4.316
Milling	0.506	0.541
Ore transfer	0.106	0.133
Gross operating expense	$3.636	$4.990

Note.—These totals do not agree with those in the report, probably because the tonnage differs in different operations. The gross operating expense in 1916, not including improvements, is stated at $2.958 and in 1918 at $4.865

The Hercules mine has the following interesting record, the tonnage being given in selected crude shipping ore and concentrates:

Tons shipped		56,446
Current mining and milling cost	$10.38	$24.02
Construction	13.64	
Freight to smelter	11.15	19.67
Treatment charges	8.52	
Total cost		$43.69
Total value free of deductions		82.69
Profit per ton		39.00

This mine started without capital and created its plant out of ore. It is interesting to note how this affects the cost of mining and also to compare the costs with those of the Bunker Hill & Sullivan which went through the same process. In twenty years the Bunker Hill mined about 3,400,000 tons of ore out of which it built up its plant, paid for costly litigation involving its very life, and fought several disastrous strikes at a cost of about $1 a ton in addition to its current operating cost of $2.60.

If the Hercules mined one ton of concentrates to four of crude, its costs were for five years:

Current operating, per ton	$2.60
Cost of plant	3.41

Doubtless when this mine shall have reached the age of the Bunker Hill its cost for construction will have diminished to about the figure attained by the latter company.

This mine has gone on successfully during the period since the preced-

ing paragraphs were written and has now become a complete mining, milling and smelting operation, but I have not obtained detailed figures regarding it. There is no reason to suppose that either its methods or its results are now essentially different from those of its neighbors.

In the first edition there was a discussion of the cost of smelting Coeur d'Alene ore by the American Smelting and Refining Company. This is no longer pertinent because that concern no longer controls the business The two largest silver-lead producers of the district, namely; the Bunker Hill and Sullivan, and the Hercles with its allied properties, have each built smelteries of their own, the first at Kellogg, the second at Northport, Washington. It is evident that both groups have seen advantages in doing their own smelting.

It is doubtful if such advantages are wholly financial. It is a natural desire on the part of owners of property to have full control of it. By the reports of the Bunker Hill and Sullivan we learn that the costs and losses incident to smelting have averaged no less than 43 per cent. of the gross value of the ore. It is rather difficult for a concern to feel independent when it surrenders so large a part of its business to others.

I think we may discern a general tendency in this direction which has become somewhat stronger in the past ten years than ever. The example was set about twenty years ago in the iron business when the smelting and manufacturing interests bought iron mines in Lake Superior until they obtained presently an overwhelming preponderance of them. It seems that the interest which demands the largest investment of capital is apt to control. In the iron business the great preponderance of investment was in the transportation, smelting and manufacturing systems; the mines were comparatively cheap, simple and easily managed. In other forms of mineral production this is not always the case. Perhaps the majority of lead and copper mines, that is such as are large enough to make a venture in smelting worth considering at all, have vastly more money invested in their mines and mills than the value of a smelting plant. The number of men employed in the different departments shows where the preponderance of effort lies; for example the St. Joseph Lead Company employs 2200 men in mining, milling and transportation, and only 350 in smelting: the Phelps-Dodge Corporation more than 6,000 in mining to 1,300 in smelting. Very likely the proportion in the Coeur d'Alenes is about the same. It is therefore scarcely to be expected that 43 per cent. of a business should be left to an outside interest, in which the relative investment and effort is only 15 or 20 per cent.

On a pre-war basis, *i.e.*, taking the average price of lead at New York at 4.5 cents and of silver at 57 cents the value of the concentrates produced by the Bunker Hill and Sullivan was about \$49.75, of which 43 per cent. would be about \$21. A first class modern smeltery may perhaps save 96 per cent. of the metals in bullion. The loss therefore

would be about $2 a ton, leaving $19 for the actual cost of smelting, refining and marketing, by contract. But with a private smelter the operating cost would have been, according to Mr. Ingalls, something as follows;

Freight, mill to smeltery?	$0.15
Reduction to bullion	5.28
Freight to refinery 43 per cent. of $10?	4.30
Refining 43 per cent. of 8.67	3.73
Total	$13.46
Apparent profit, say	5.50

Whether such a profit is actually realizable, or is realized, depends upon some factors which I have not been able to analyse; for instance, the cost of coke and fluxes required for reduction as compared with the costs of those things at the points where the American Smelting & Refining Company did its smelting, and also the correctness of the freight rates. I have no positive data upon which to base an opinion. It is very probable that the factors upon which the operations of the new smelters is based are not by any means settled. A higher level of prices has developed in all departments, making higher costs for transportation, fuel and refining in a proportion varying from 60 to 100 per cent.

It is certain that in the case of the Bunker Hill and Sullivan the capital costs to be charged against the operating profit in smelting are somewhat as follows:

Amortization of smelting plant on say 20 years life, about 11 per cent of $1,500,000 is per year	$165,000
Use of $1,500,000 working capital at 6 per cent	90,000
Depreciation charges 6 per cent. on cost of smelting	90,000
Total	$345,000

The cost per ton of concentrates will be determined by the number of tons treated. At 100,000 tons a year it would be $3.45. On a pre-war basis such a capital cost would be high, but on the present basis it does not seem so.

Federal Mining & Smelting Company

This concern was for some ten years the largest producer of silver-lead ores in the Cœur d'Alene district, but recently it has been in a state of decline. The principal object of describing it is to exhibit an example of the exhaustion of mines, a fate which is often put off in a manner that disconcerts one who expects it, but which comes nevertheless. A group of four of the best mines of the district has now dwindled down to a single survivor. These properties had the following history:

The Last Chance group at Wardner was, about 1900, a bonanza mine owning a portion of the Bunker Hill lode and one or two other productive veins. That portion of the mine that was being operated actively was worked to the boundaries and finally abandoned. The remaining unexplored territory, together with certain pretensions of extralateral rights, was sold to the Bunker Hill and Sullivan for 9 per cent. of the stock of that company. This sale occurrred in 1910.

The Tiger-Poorman vein at Burke, owned wholly by this company, became unprofitable at a depth of 1800 feet and was abandoned.

The Standard-Mammoth lode, on which were the openings of the Standard, Mammoth and Greenhill-Cleveland properties, was worked continuously and heavily from 1892 to 1917, but became exhausted at a vertical depth of about 4000 ft. A little ore perhaps remains in the Greenhill-Cleveland. The total production of this lode was about 5,000,000 tons of crude ore and perhaps 800,000 tons of concentrates containing 450,000 tons of lead and over 40,000,000 ounces of silver. I do not pretend that these figures are accurate but give them merely to present an idea of the productivity of a first class vein in this region.

The Morning mine is still being worked. The ore has always presented some difficulties. It occurs in great volume, but has been low in silver, high in zinc, difficult to concentrate, and wet. The mine is now very deep, about 3500 feet vertically; ventilation is difficult. The total output to date has been about 5,000,000 tons crude and this will ultimately rise at least to the neighborhood of 8,000,000 tons. During the war years, 1916, 1917 and 1918 this mine was able to earn over $1,000-000 a year, but under normal conditions the profits were, and may be expected to be, meager.

The total output and profits of this group since 1909 is shown by the table.

	Tons crude ore	Tons shipping product	Price of lead per pound, cents	Profits	Dividends
1910	741,650	107,826	3.885	$743,807	$839,027
1911	784,600	118,315	4.45	1,241,115	839,027
1912	836,947	118,734	4.35	895,429	749,131
1913	691,487	84,533	3.90	883,448	719,166
1914	421,631	57,058	3.50	552,396	599,305
1915	461,252	66,610	4.00	310,367	479,444
1916	Not given	137,390	5.06	868,198	509,409
1917	728,539	130,097	6.10	Not given	839,027
8 years	5,400,000	appr. 820,563		6,750,000?	$5,573,536

In these statistics no account is taken of shipments of zinc ore except probably for the two last years, for which however it is not stated separately. In a general way we may compute the total output at 330,000 tons metallic lead and about 17,000,000 ounces silver. The value of the silver would equal perhaps 125,000 tons lead. We cannot be far wrong therefore to conclude that approximately 450,000 tons of lead, or its equivalent, yielded about $6,750,000 profit, about $15 per ton. To bring the profits up to this figure the exceptional years 1916 and 1917 have to be included.

But in this connection it is well to observe that the company never realizes the full market price of its lead. Through its contract with the American Smelting and Refining Company it receives 81 per cent. of the market price up to 4.1 cents per pound and above that, when the price rises, one half the additional. It was against terms of this kind that the neighboring companies revolted and built their own smelteries.

Broken Hill Proprietary

This great company is no longer particularly a lead producer. It still operates its mine at Broken Hill, but chiefly for zinc and with an output of only about 160,000 tons a year of lead. It has gone into the steel business, apparently on a comprehensive, but from the American standpoint rather a moderate, scale. In 15 years ending in May, 1918 it treated 3,436,886 tons of tailings by flotation and recovered 853,364 tons of zinc concentrates. Following are the remarks on its silver-lead business that appeared in the first edition.

Costs in the Broken Hill District.—For an interesting comparison let us turn from the Cœur d'Alene to the Broken Hill district in Australia, where the Broken Hill Proprietary mine is by far the greatest lead-silver producer in the world. This property has produced in eight years of which reports are available to me, 4,001,969 long tons of ore, which yielded 398,470 long tons of lead, 35,504,331 oz. silver, and 32,886 oz. gold. Reducing this to terms of short tons in order to make comparison with American mines more obvious, we have 4,482,202 short tons, yielding 9.95 per cent. lead, 7.92 oz. silver, and 0.008 oz. gold. The cost for mining, concentrating, smelting, refining, marketing, general expenses, and depreciation has been exactly $9 per ton.

The cost statements issued by this company look upon the whole operation as a unit, *i.e.*, no sharp line is drawn between mining, concentrating, and smelting. As nearly as I can judge, however, the costs per ton for the year 1906 were divided as shown below.

The costs seem to be near enough the average to give a fair conception of the general results. The figures covering depreciation are adequate. About $2,000,000 has been written off the accounts in eight

Short tons mined, 653,362	
Cost of mining and development	$3.01
Concentration	1.06
Smelting, refining, and marketing	3.86
General expense and depreciation	0.75
Total	$8.68

years and the whole plant of this great concern stands on the books at the end of the period at only $1,933,575. There were 3,000,000 tons of ore then developed.

The costs of this mine are high, owing to unfavorable external factors. The climate is extremely arid; the country is a desert. Fuel, water, labor, and transportation are all expensive. As a good example let us take the fuel and flux account which amounted to $1.39 per ton, about twice as much as would be required for mining and smelting the same amount of Cœur d'Alene ore at the points where the work is done. Mine timber costs 30 cents per ton mined, twice as much as at the Bunker Hill. These figures indicate such a set of external factors as to explain why it costs $4.07 per ton for mining and concentrating at the Broken Hill against $3 or less in the Cœur d'Alenes. The internal factors for mining are good.

On the smelting side we find that the proportion to be smelted is high, being one ton in 2.9, against one ton in 5.84 at the Bunker Hill. The actual cost for smelting, refining, and marketing Broken Hill concentrates is $11.19 per ton smelted. This includes freight on ores from the mine at Broken Hill, N.S.W., to Port Pirie, which is $2.12 per short ton. It does not seem to include freight on bullion from Port Pirie to market. Costs mean the production of metals ready for delivery at Port Pirie. These facts seem to permit of the following comparison with American results on Cœur d'Alene;

	Broken Hill	Cœur d'Alene
Freight from mine to smelter, neglecting moisture	$2.12	$8.00
Freight, smelter to refinery		2.90
Smelting	9.07	5.28
Refining		3.99

It appears, therefore, that for equivalent work the American practice in smelting costs about the same as the Australian. We find that Broken Hill ores averaging 28.8 per cent. lead cost for actual smelting and refining $9.07 per ton against $9.27 per ton for smelting and refining Cœur d'Alene ores averaging 46 per cent. lead. The freight in American practice performs the triple function of bringing the ores nearer to bases of fuel supply, of bringing them in contact with other ores that can be profitably smelted in conjunction, and of bringing them nearer the markets where they are to be finally sold.

If the freight items are to be neglected entirely the comparison is unfair to the Broken Hill work, because that company, while not paying freight on its ore beyond Port Pirie, does pay freight on its fuel and other smelting supplies to Port Pirie. We are, therefore, brought to conclude that there are no figures for determining just what differences there are in smelting and refining costs between the Broken Hill and the American works. It is quite plain that mining and milling are more costly in Broken Hill than in the Cœur d'Alene and that for this the unfavorable external factors of the Australian desert are a sufficient explanation.

Taking the average cost of working the Broken Hill ores at $9 per ton and assuming that the products sell in the proportion of 3.15 cents[1] per pound for lead, and 60 cents per ounce of silver, we find that Broken Hill ores are worth $11 a ton, and that lead during the period reviewed has cost 2.78 cents per pound, silver 49 cents per ounce, and gold $18 per ounce.

Lead and Silver from Park City, Utah.—In this important district there are, (1) ore deposits in fault fissures, and (2) replacement deposits in limestone. Of the fissure veins worked thus far only one, the Ontario, has been remunerative. It seems that geologically the ores are all of fissure origin. A great flat formation of quartzite is overlaid by 200 ft. of limestone; the limestone is covered in turn by a bed of soft black shale. Faults traversing the formation produce fracturing in the quartzites and limestones, and form channels for the ready circulation of water; in the shales the fissures are entirely closed up.

The result is that the mineralization caused by waters flowing upward through fissures is stopped by the shale and compelled to seek out lateral channels in the limestone. Waters of this origin have caused the deposition of important orebodies in the limestones and quartzites. The fissuring has served to facilitate the circulation laterally fully as much as vertically. In some cases the ultimate source of the mineralization is unknown; but in other cases the flat ore shoots in the limestone were fed from the Ontario fissure.

The Ontario mine was practically worked out many years ago. i nce 1893 most of the ore has come from the limestone deposits. Of hese the principal mines are the Daly-West, the Daly-Judge and the Silver King. These mines are very simi'ar. The orebodies usually have a pitch of between 5 and 15° from the horizontal, and are from 50 to 200 ft. wide, and from 3 to 30 ft. thick. They follow fissures, and hence have fairly well defined courses for considerable distances, but they frequently leave one fissure to follow another. Where the limestone is brecciated at the intersection of fissures the orebodies are largest.

[1] I have assumed 4.6 cents per pound as an average price for American lead. The tariff makes the difference.

The original ore was a mixture of sulphides of iron, lead, copper, and zinc, carrying considerable silver and some gold. Oxidation has effected an important rearrangement. Nearest the surface the ores are lead carbonates free from zinc; lower are lead sulphides rich in silver, but free from zinc; lower still there has been an important regeneration of zinc blende, and at this zone the ores are much inferior in lead and silver content. The zinc regeneration is immediately above the unaltered sulphides; these are sometimes payable, but have not been worked much.

Costs at Park City Mines.—A great deal of gangue occurs in the ore and must be sorted out. At the same time much of the ore is high-grade and cannot be improved by concentration; one-third to one-half of the ore mined is of this character. Exploration and development are expensive, owing to the dip and irregularity of the orebodies. These external factors make the costs high.

The external factors are about the average for the Rocky Mountain region.

Daly-West Production in Seven Years, 1900–1906

Crude ore shipped direct		224,418
Ore milled		489,415
Total		713,833
Concentrates shipped		97,634
Total shipments		322,052
Lead, 73,942 tons, at $92		$6,800,000
Silver, 17,167,000 oz., at 57 cents		9,785,000
Gold, 13,847 oz., at $20.67		280,000
Copper, 12,164,000 lb., at 15 cents		1,800,000
Total value		$18,665,000
		$58 per ton
Freight, treatment, and deductions	$8,327,000 =	$25.83 per ton
Cost of mining and milling		13.72 per ton
Total cost		$39.58 per ton
Profit per ton shipped		18.42

Results per Ton Mined

Average value, $28.40.	
Cost of mining and milling	$6.26
Milling losses, average 8 per cent.[1]	2.24
Freight, smelting, refining, and deductions	11.66
Total cost	$20.16
Profit per ton mined	8.24

[1] See explanation below.

SUMMARY OF DALY-WEST COSTS—1900 TO 1906 INCLUSIVE

	Per ton mined and milled	Per ton ore and concentrates shipped
General expense	$0.42	$ 0.92
Exploration and development	0.60	1.31
Mining	3.38	7.40
Milling (Per ton milled $1.36)	1.00	2.19
Construction	0.30	0.66
Shipping and selling	0.56	1.24
	$6.26	$13.72

One may indulge a little skepticism as to the accuracy of these reported savings in the lead. It seems that the ore must have been assayed for lead by fire assay which gives inaccurate results, or there must have been errors in sampling and weighing. I prefer to believe

	Lead, per cent.	Silver, per cent.
1900	92.00	67.69
1901	92.87	70.16
1902	93.00	72.00
1903	97.9	72.3
1904	99.00	70.5
1905	99.5	72.5
1906	98.44	73.04

that the saving of lead was about the same as that reported for silver. We may lump the whole mill saving roughly at 75 per cent. On this basis the mill losses would be about 8 per cent. of the entire product.

The Daly-Judge mine is west of the Daly-West, and the ore-bodies are in the zone of zinc regeneration, or in the original sulphides underlying that zone. The mine has not been very profitable. Attempts have been made to improve the mill from time to time and the result has been a considerable cost for construction, but since the improvements do not seem to guarantee future earnings the construction should probably all be charged to operating.

SIX YEAR'S OPERATION, DALY-JUDGE MINE (213,000 TONS)

Lead, 19,375 tons	$1,785,000
Silver, 1,390,000 oz	792,000
Gold, 4,800 oz	99,000
Copper, 272,000 lb	41,000
Zinc, 8,614 tons	900,000
Total value	$3,617,000

Cost of smelting, refining, and marketing and smelter deductions (losses)	total	$1,845,000
	per ton	$8.66
Mining and milling costs		7.27
Probable mill losses		3.00
Total costs and losses		$18.98
Profit		1.00
Total value of ore as mined		$19.93

DETAILS OF COST FOR 1907

Mining	$3.03
Exploration and development	0.40
Concentrating	0.95
Shipping and selling	0.33
General expense	0.53
Construction	0.21
Total	$5.45

These costs are lower than the average. During the period under review the mine was shut down for two years in order to prosecute development. Development in the whole period has averaged about $1.50 per ton.

The Silver King is a rich and profitable mine. It does not publish reports, but its costs are approximately $9.40 per ton mined and milled and $15.50 per ton of selected ore and concentrates shipped. The ore is richer than the Daly-West in lead and much richer in gold, but about the same in silver.

The Park City ores present the following factors making high costs; (1) Relatively small orebodies that must be followed over large areas, thus establishing a high cost for exploration and development: (2) a careful selection of the ores and the rejection of large amounts of waste: (3) a large percentage to be smelted and a very high charge for smelting.

Smelting Costs Applied to Park City Ores.—Let us take the average ore produced by the Daly-West mine and calculate smelting results on it, assuming a freight rate of $1.50 per ton to Salt Lake from the mines, and prices of 4.6 cents per pound lead, 15 cents per pound copper, and 60 cents per ounce silver. Let us assume also that all refining is done at the Atlantic seaboard. The lead and copper together amount to almost exactly 25 per cent. of the ore.

The assay of shipping product is as follows:

		Gross value New York
Lead	22.96 per cent.	= $21.12
Copper	1.89 per cent.	= 5.67
Silver	53.31 ounces	= 31.99
Gold	.043 ounces	= 0.87
		$59.65

Freight to Salt Lake on concentrates		$1.50
Freight to New York on bullion 25 per cent. of $10.80		2.70
Refining 25 per cent. of $8.67		2.17
Reduction to bullion		5.28
Losses 3 per cent. silver	0.96	
6 per cent. lead	1.27	
33½ per cent. copper	1.89	4.12
		$15.77

The actual deductions for freight, treatment and losses, were $25.86 per ton, so that we must estimate a profit of $10.09. This is a very different result from that obtained in the case of Cœur d'Alene ores.

Assuming that these figures are not far from the truth, and assuming 2.2 tons mined to one ton shipped, we have for the whole problem of silver-lead ores at Park City the following mininum costs per ton mined, as shown by the experience of the last seven years:

Mining, milling, and all costs to mining company	$6.26
Smelting, refining, and marketing	7.17
Total	$13.43

Since mill losses must be estimated at not less than 10 per cent. on low-grade ores and smelting losses at 5 per cent. more, the actual costs can only be 85 per cent. of the original value. In round numbers, therefore, an ore in Park City must be worth $15 a ton before there can be a profit in it for anybody. At average prices this figures about 11 per cent. lead and 9 oz. silver.

CHAPTER XXII

THE COST OF SILVER-LEAD SMELTING[1]

BLAST-FURNACE OPERATION—ROASTING—COST OF SMELTING PLANT—CALCULATION OF INTEREST AND AMORTIZATION—FUNCTIONS OF COPPER IN LEAD SMELTING—FREIGHT AND REFINING—COST OF REFINERIES—AMERICAN SMELTING AND REFINING COMPANY—HISTORY AND STATISTICS—TONNAGE SMELTED—AVERAGE GRADE OF ORE—GROWTH OF PROFITS—DIVISION OF ORE VALUE—COSTS AND CONTRACTS ON AVERAGE ORE—CONCLUSIONS REGARDING DERIVATION OF PROFITS.

The cost of smelting and refining in the United States ranges widely among the various plants, depending upon the size and nature of the plant; the cost of labor, fuel, fluxes, and material; the character of the ores smelted, etc. Thus, nine plants during the same period of six months, a few years ago, showed costs of smelting referring to the blast-furnace operation only, per ton of charge (ore and flux), which ranged from \$2.50 to \$4.80. This appears in the following list: A, \$3.418; B, \$2.525; C, \$3.260; D, \$3.331; E, \$3.754; F, \$3.929; G, 3.929; H, \$4.039; I, \$4.781. Average, \$3.607.

In the treatment of the argentiferous ores of the West, the present practice is to roast only those that are low in lead, and charge raw into the blast-furnace the rich galena. The cost of roasting is \$2 to \$2.50 per ton of ore roasted. The cost of smelting a ton of charge in a large modern plant, under favorable conditions, is about \$2.50, of which about 84 cents is for coke and \$1.66 for labor, power, and supplies. The expense of administration amounts to about 16 cents additional. Consequently, the total cost per ton of charge (ore and flux) is about \$2.66. If the ore amounts to 80 per cent. of the charge, which corresponds to the ordinarily good practice, the cost per ton of ore is about \$3.33.

An average of the work of many large smelting plants shows that for every ton of charge smelted in the blast furnace, about 0.4 ton of material (ore and matte) must be roasted. The cost of roasting ranges from \$2 to \$2.50 per ton. Taking the lower figure, in view of economies that have been effected by the blast-roasting process, we may figure that on the average 80 cents is to be added to the cost of smelting, making the total cost per ton of ore about \$4.12. Figuring on the same basis of 80 per cent. of ore in the charge, the average for the nine works previously mentioned would be \$3.607 ÷ 0.80 = \$4.50 approximately.

[1] This article is a condensation of one published originally in *Eng. and Min. Jour.*, of Aug. 15, 1908. While the present article is greatly condensed from the original, certain points have been amplified and figures have been brought up to date.

Interest Charges, Amortization, etc.—Works, capable of smelting 1000 tons of ore per day, or roughly 330,000 tons per annum, cost nearly $1,000,000, or about $3 per ton of annual capacity. Reckoning amortization at 10 per cent. per annum, and interest on the investment at 6 per cent., the smelter must add 48 cents per ton of ore smelted on account of these fixed charges. Moreover, the smelter is bound to carry a large stock of ore on hand. Assuming that the works which is treating 330,000 tons of ore per annum has always 30,000 tons on hand, and that the average value of the ore is $30 per ton, the interest charge on each ton of ore smelted is upward of 15 cents. A month's delay in realizing on the products adds 15 cents more.[1] This makes a total of $5.28 up to the production of base bullion. The smelter recovers about 95 per cent. of the lead and 97 per cent. of the silver in the original ore. He pays the miner for only 90 per cent. of the lead and 95 per cent. of the silver, wherefore he has a certain leeway on these metals, as he may have also on gold for which he pays the miner only 95 per cent., but recovers 100 per cent.[2]

Copper.—Besides the gold, silver, and lead of the ore there is a certain amount of copper, modern practice demanding the presence of 0.5 to 1 per cent. in the charge in order to insure a clean slag. This copper goes partly into the slag, and partly into the base bullion (from which it is recovered during the refining process), but chiefly it is obtained in the form of matte, which is concentrated up to about 40 per cent. copper and then is despatched to Omaha, where it is converted into blister copper. The converting of this leady matte is more costly than the treatment of ordinary copper matte, and indeed throughout the lead smelting process copper is subject to high losses, especially in the slag of the first smelting, which follows from the common metallurgical principle that losses are quantitatively constant (or nearly so) and proportionately variable. Consequently in the treatment of an ore so low in copper as 0.5 to 1 per cent. the percentage of loss is large. It may be generalized as 30 per cent. It is for this reason that the smelter makes

[1] It will appear subsequently that this estimate of the time that ore and crude metal are in process of treatment is under, rather than over, the average. As a matter of fact smelters roughly figure interest on the basis of 90 days.

[2] The actual extraction of lead is less than 95 per cent., but in good practice it is 95 per cent. on the basis of fire assay, on which much of the ore is purchased, so it is proper to figure 95 per cent. However, this is drawing it rather tightly upon the smelter, and considering the further loss of 1 per cent. which the lead suffers in refining the smelter who pays for 90 per cent. of the lead in the ore does not obtain any great margin on this item, nor does he on the purchase of the silver. The smelter does not really recover 100 per cent. of the gold, although he may apparently do so, and even more, because of the cumulative effect of small amounts of gold, too little to figure in the ore settlements, which give the smelter more to start with than his books show.

so large a deduction from the copper in the ore (1.3 units from the wet assay) and pays for it at 3 to 7 cents less than the price of refined copper at New York. Of course it will be understood that the deduction of 1.3 units pertains to ores that contain sufficient copper to deserve payment, and that those ores when mixed with many others that contain no copper give an average furnace charge with 0.5 to 1 per cent. copper. It may be explained also that all of the copper does not finally appear as refined metal, a fairly large quantity being obtained and marketed as bluestone. In the generalization which I am attempting it is impossible to go far into these details.

Freight and Refining.—The products of the smelteries are base bullion and lead-copper matte. The latter goes to Omaha for converting and the blister copper thence is passed on to Perth Amboy for refining. The base bullion goes to Denver, Omaha, Chicago, and Perth Amboy. As in the case of smelting there are differences among these works as to the cost of refining and other conditions, but inasmuch as the prices for lead and copper are based on the market at New York it is best to confine attention to the refining and handling of base bullion at that center.

The freight rate on base bullion from Salt Lake City to New York is $10.80 per ton; from Denver and Pueblo to New York it is $6.40 per ton. The cost of refining is $6 to $6.50.[1] Other costs are lighterage, $0.625; selling, $0.40; miscellaneous, $0.325. This gives a total of $7.60 exclusive of freight. The cost of a lead refinery is about $6.66 per ton of annual capacity, on which amortization at 10 per cent. and interest at 6 per cent. come to $1.07, making the total cost of refining, lighterage, selling, etc., about $8.67. Consequently, the charges on a ton of ore smelted at Salt Lake and yielding 10 per cent. of lead are as follows: Smelting, $5.28; freight on bullion, $1.08; refining, etc., $0.87; total, $7.23.

In addition to this total, the reports of the American Smelting and Refining Company indicate a general expense amounting to 25 to 40 cents per ton of ore smelted, the smaller figure being achieved in the more recent years Consequently we may put the total cost of smelting and refining at about $7.50 per ton of ore.

In custom-refining it is the practice to pay the smelter, *i.e.*, the seller of the base bullion, for the gold at $20 per ounce; for the silver at the New York price less 1 cent per ounce (this is 98 per cent when silver is worth 50 cents per ounce); and for the lead at 98 per cent. of the New York price. The actual extraction of lead is 99 per cent. The loss of silver is so small that it may be disregarded for present purposes.

[1] At Chicago the cost is only $4, and under favorable conditions lead refining should be done at that figure.

American Smelting and Refining Company.—The reports of this company throw but little light upon the subject of the cost of smelting. Its statement of assets, gross earnings, profits, etc., for a series of seven years, is given in the accompanying tables. Before proceeding to discuss these figures, it is important to make certain explanations. In each year the figures are for the fiscal period ending April 30, wherefore the major part of the period pertains to the preceding calendar year. The item that I have entered as "Repairs" is given in the reports of the company as "Ordinary Repairs and Betterments." What I have called "General Expense" includes all of the general expenses of administration, together with interest and taxes. "Net Earnings," so-called by the company, are evidently not properly designated, being merely the operating profit. The true profit, or actual net earnings, appears later in what the company calls "Net Income." Under "Improvements," I have entered what the company calls "Appropriation for Extraordinary Improvements and New Construction." From the uniformity of this account, I judge that it represents chiefly the new construction undertaken to replace worn-out or antiquated plant; in other words, it is in this way that the company makes good the depreciation of its property, which otherwise would have to appear in an amortization account.

Except in its recent statement to the New York Stock Exchange that the average amount of ore smelted is 3,500,000 tons per annum, the smelting company has never made any statement of its production of metals or amount of ore smelted. The nearest that it has come to communicating this important information was in the report for the fiscal year ended April 30, 1903, wherein it stated that the volume of business transacted during the year is reflected in the following figures: Metal content of ore purchased: gold, 1,025,132 oz.; silver,62,389,438 oz.; lead, 492,960,350 lb.; copper, 47,919,666 lb. Fuel consumption: coal, 544,790 tons; coke, 433,431 tons; fuel oil, 3,523,904 gal. Freight traffic: total tonnage moved, 4,434,484.

Year	1903	1904	1905
Property account	$86,845,671	$86,845,671	$86,845,671
Investment account	1,028,598	1,680,306	(*a*) 3,982,576
Metal stock (Au., Ag., Pb., Cu.)	18,010,687	17,032,300	16,418,543
Material, fuel, flux	1,107,253	1,224,688	1,118,902
Cash	2,339,154	4,047,423	4,636,649
Total assets	$109,331,362	$110,830,387	$113,002,340

(*a*) Does not include 177,510 shares of the common stock, American Smelters Securities Company, par value $17,751,000.

(*b*) Includes $500,526 as "net current assets."

Year	1906	1907	1908
Property account	$86,845,671	$86,845,671	$86,845,671
Investment account	(a)4,179,915	(a) 3,810,595	3,950,088
Metal stock (Au., Ag., Pb., Cu.)	19,415,200	18,251,587	17,519,664
Material, fuel, flux	1,114,893	1,317,544	1,380,742
Cash	4,757,929	6,706,984	5,629,034
Total assets	$116,313,607	$116,932,381	(b)$115,825,725

II. A. S. and R. Co. Comparative Statement of Income Account

Year	1902	1903	1904	1905
1. Earnings	$7,038,682	$9,403,711	$9,425,443	$10,506,683
2. Repairs	791,306	770,854	818,141	878,648
3. General expense	1,385,757	1,056,786	701,729	729,224
4. Net earnings	4,861,619	7,576,786	7,905,573	8,898,811
5. Employees' fund	....	....	91,254	216,816
6. Improvements	....	655,683	597,582	425,289
7. Metal account	1,300,000	1,500,000	500,000	637,795
8. Net income	3,561,619	5,421,103	6,716,737	7,618,912
9. Dividends	3,500,000	3,500,000	4,750,000	6,000,000
10. Surplus for year	61,619	1,921,103	1,966,737	1,618,912
11. Total surplus	2,951,968	4,873,071	6,839,808	8,458,720

Year	1906	1907	1908
1. Earnings	$11,665,886	$13,250,058	$9,403,282
2. Repairs	828,582	976,535	933,130
3. General expense	675,945	763,854	836,866
4. Net earnings	10,161,358	11,509,669	7,633,287
5. Employees'fund	449,204	540,420	*Nil.*
6. Improvements	938,100	1,054,996	622,096
7. Metal account	*Nil.*	*Nil*	*Nil.*
8. Net income	8,775,055	9,914,253	7,011,191
9. Dividends	6,750,000	7,000,000	....
10. Surplus for year	2,024,055	2,914,253	11,191
11. Total surplus	10,482,775	13,397,028	13,408,219

Tonnage of Ore Smelted.—These data enable us to arrive approximately at the amount of ore purchased, and we may assume that the amount smelted was approximately the same. It is a fair assumption that the ores were purchased in substantially the proportions required to make a suitable smelting mixture, and that the lead content was in the neighborhood of 10 per cent. of the total ore. The purchase of 246,480 tons of lead would therefore imply 2,464,800 tons of ore. Some of the copper purchased was included with the lead charge, but some was

smelted separately. As to this particular I can do no more than surmise that 100,000 tons of copper ore may have been smelted separately, and that the total amount of ore smelted by the company in this year was about 2,564,800 tons. It will appear that this estimate is probably not far out of the way. In 1901 the American plants of the company alone were smelting at the rate of about 2,000,000 tons of ore per annum, and from that time onward business increased. In the fiscal year ending April 30, 1903, the total movement of freight is given as 4,434,484 tons. Deducting 991,221 tons for fuel (allowing 13,000 tons for the oil) and 270,439 tons of lead and copper, we have left 3,172,824 tons for ore and limestone, of which the latter would normally be about one-sixth, deducting which there remains 2,644,018 tons for ore. There is some traffic in matte and other products from one works to another, but making allowance for such duplications and overestimates it seems not unreasonable to assume 2,500,000 tons of ore smelted. On this basis, namely 2,500,000 tons, it appears that the total actual profit to the company in the year ending April 30, 1903, was a little less than $2.20 per ton of ore. Inasmuch as this is determined by making the tonnage the divisor of the whole profit of the company and it is not to be doubted that even in 1902–03 the company was making handsome returns from its mercantile and investment accounts. I believe it is reasonable to assume that its profit in smelting properly considered, at that time may have been about $2 per ton. Mr. Edward Brush, of the company, before the Ways and Means Committee, December 16, 1908, stated that in the fiscal year ended April 30, 1908, the company smelted 3,372,750 tons of ore. The net profit in that year was $7,011,191. Consequently the total profit per ton of ore was a little less than $2.08. The actual smelting profit was, of course, something less, because the company realizes more or less from its various ventures that are not to be referred directly to its smelting business.

Average Grade of the Ore.—The figures given for the fiscal year ending April 30, 1903, also convey valuable information respecting the average metal contents of the ore smelted in the United States and Mexico. Proceeding still on the assumption that the total tonnage was 2,500,000, the average was 0.41 oz. gold, 24.95 oz. silver, 197.4 lb. lead, and 19.17 lb. copper. The substantial accuracy of this deduction is confirmed by the report of the census for 1904. (The census confusingly designates the year as 1905, because its investigation was made at that time, but the investigation related to 1904.) According to the census, the amount of argentiferous ore treated in 1904 was 2,271,724 tons, which yielded an average of 0.42 oz. gold, 16.53 oz. silver, 198 lb. lead, and 22.72 lb. copper. It is to be remarked that the figures of the census relate only to ore smelted in the United States, while my previous figures have included the ore smelted both in the United States and in

Mexico. Moreover, the latter figures are for contents of the ore purchased, while the census figures are for yield of the ore. However, the agreement is sufficiently close to confirm the belief that my estimate is a close approximation.

Another interesting deduction may be made from the statistics of the smelting company for the year ending April 30, 1903. During that period, the average price for silver was 50¼ cents per ounce; of copper, 12.452 cents per pound; of lead, 4.147 cents per pound. Computing ore of the average grade shown for the year ending April 30, 1903, on the basis of 100 per cent. of the metal contents at the average New York prices for silver, lead, and copper, and $20.56 per ounce for gold (which is what the United States Smelting, Refining, and Mining Company realized for its product in 1907, although the coinage value of gold is $20.67 per ounce), it appears that the maximum gross value of this average ore was $31.54 per ton, itemized as follows: 0.41 oz. gold at $20.56, $8.4296; 24.95 oz. silver at 50¼ cents, $12.5374; 197.3 lb. lead at 4.147 cents, $8.1820; 19.17 lb. copper at 12.45 cents, $2.3867. Total, $31.5357. Having already shown that the average profit per ton of ore smelted in that period was probably about $2, the actual net profit to the smelter was a little more than 6¼ per cent. of the ore value.

Subsequent Increase in Profits.—It is impossible to follow analytically the subsequent history of the company in any way that has a very sound foundation. The reports show a marvelous increase in the profits, which were $5,421,103 in 1902–03 and $9,914,253 in 1906–07. During this period of four years the amount of ore smelted by the company increased greatly, but there is no reason to surmise that it increased in the same ratio as the profits: indeed, there is sufficient evidence to warrant me in saying positively that it did not, and that if the tonnage of ore smelted in each year were made the divisor of the net profits reported the quotients would be steadily increasing up to the last year or two. However, any such figuring would be misleading, because the company has undergone great expansion and derived greatly increased profits from sources that are not properly referable to the direct smelting operations. The company avers that it has not increased treatment charges, and there is much evidence in support of that assertion.

Explanation of Increasing Profits.—In directing attention to the subject of the increasing profit shown by the reports of the smelting company, it is important to consider a variety of conditions. It is well known that it is much more economical to smelt on a copper basis than on a lead basis. The difference in favor of the former is fully $1 per ton of ore. Consequently, the more copper ore to be smelted, the more the profit, and the increasing net earnings of the smelting company are doubtless due to some extent to the increased amount of ore smelted on the copper basis. It is also well known that the margin on ore purchased

in Mexico is much greater than on American ores, and a large part of the profit of the smelting company is derived from its Mexican business, which has been rapidly increasing. The lowest margin, probably, is realized by the smelteries in Colorado, which until lately have treated in the neighborhood of 1,000,000 tons per annum and operate rather uniformly at that rate. A few years ago the profit in smelting in Colorado was only about $1 per ton, and probably it is no larger at the present time. It is claimed also that the profit in smelting in Utah has been only about $1 per ton since competition has been active at that point. On the other hand the profit at non-competitive points and in Mexico must be large.

The increase in the earnings of the smelting company has also been promoted without doubt by its profit-sharing system, which was designed to increase efficiency and has had that effect. The company has benefited from economies in administration, as is clearly shown by the decreasing amount to the account of general expense. Furthermore, it has derived great advantage from the introduction of metallurgical improvements, such as the Huntington-Heberlein process, and the concentration of operations at the most economical plants. Finally, we come to the question of metal stock account, wherein the purchaser of ores may lose or make a great deal through fluctuation in the value of the metals. In the long run such fluctuations are expected to balance, and temporary gains or losses are commonly charged to an account representing quotational profit or loss. In a long upward trend of prices, a buyer of ores may realize a great profit; and similarly in a sharp decline, he may suffer an immense loss. From 1901 to the end of 1907 the general trend of the metal markets was upward, and undoubtedly the greatest factor in the increase in net income up to April 30, 1907, was the appreciation in the value of metals on its hands, just as since June, 1907, its net income suffered severely from the decline. The company carries in its statement of assets an item of "metal stock" ranging from $16,418,543 to $19,415,200, which represents its valuation of ores and metals on hand. The nature of its business requires that large quantities of ore and crude metal be in stock at all times. It appears from the data deduced in this article that the stock necessarily carried is from 20 to 25 per cent. of the annual turnover; in other words, the ore and its products are in process of treatment and in transportation for 2½ to 3 months.

Division of Ore Value.—Now let us see what division is made of the value of an ore assaying 0.41 oz. gold, 24.95 oz. silver, 179.3 lb. lead, and 19.17 lb. copper, which was the composite of all the ore bought by the American Smelting and Refining Company in 1902–03. The smelter and refiner probably realized, from this ore approximately as follows: gold, 0.41 oz. at $20.56, $8.43; silver, 24.95 oz. × 0.97 at 50¼ cents, $12.16; lead, 197.3 lb. × 0.94 at 4.147 cents, $7.69; copper, 19.17 lb. × 0.7 at 12.45 cents, $1.67. Total, $29.95.

The expenses from the time of receipt of the ore at the smelting works to the sale of the refined metals are approximately as follows:

1. Smelting, 1 ton at $4.50	$4.50
2. Converting 40 lb. copper matte at 0.7 cents	0.28
3. Freight on 190 lb. lead bullion at 0.43 cents	0.82
4. Freight on 13½ lb. copper bullion at 0.5 cents	0.07
5. Refining 190 lb. lead bullion at 0.38 cents	0.72
6. Refining 13½ lb. copper bullion at 0.7 cents	0.09
7. General expense	0.40
8. Amortization	0.25
9. Tie-up of metals	0.30
10. Metal account	0.30
Total	$7.73

1. As previously computed. 3. The rate of 0.43 cents is the mean of the rates from Salt Lake and Pueblo; this assumption is necessarily arbitrary. 4. In this case also the assumption of freight rate is necessarily arbitrary. It is intended to cover all freight charges on copper from the time of leaving the first smelter. Copper matte goes to Omaha from East Helena, Salt Lake, Denver, Pueblo, and elsewhere—even from Perth Amboy—and the copper bullion thence goes to Perth Amboy. Probably the assumption of 0.5 cents per pound to cover all of this movement is too low. 7, 8. These figures are deduced from the reports of the American Smelting and Refining Company; the allowance for amortization appears to be too low. 9. As previously computed. 10. This appears to be the average allowance that has been made by the American Smelting and Refining Company, as insurance against depreciation of metals on its hands.

Inasmuch as the smelter is supposed to realize a profit of $2 per ton of ore, the total deduction for its account must be $7.73 + $2 = $9.73, and from the value of the ore, $29.95, there is left $29.95 − $9.73 = $20.22 to pay for the ore and the freight upon it to the smelting works.

Now let us see how that would figure out to the producer. We may assume a settlement on the lines of the following: gold, 0.41 oz. at $19.50, $8; silver, 24.95 oz. × 0.95 × 50¼ cents, $11.91; lead, 197.3 lb. at 2 cents, $3.95; copper, 19.17 lb. at 5.45 cents, $1.04; total, $24.90; deducting a treatment charge of $4.68 leaves $20.22 as the net value to producer. This corresponds to an ore contract reading, "Gold to be paid for at $19.50 per oz.; silver at 95 per cent. of the New York quotation; lead at 40 cents per unit; copper at the New York quotation, less 7 cents per pound; treatment charge, $4.68 per ton; neutral basis; delivery at smelter's works." This has a familiar sound, except that so small a percentage of copper is not always paid for, but it must be remembered that I am here figuring on a composite ore, the copper of which is obtained chiefly in special classes of a higher average of all ores smelted.

Conclusions.—After a consideration of the data, it is impossible to escape the conclusion that the great increase in the net earnings of the American Smelting and Refining Company from year to year is to be attributed to: 1. Enlargement in the volume of business. 2. Institution of economies (*a*) in administration; (*b*) through centralization of operations; (*c*) through metallurgical improvements; (*d*) through increase in operative efficiency. 3. Appreciation in the value of metals, due partly to natural causes, and partly to manipulations by the company. The profits on exempt lead, and on contracts with the producers of lead ore, whereby the value in excess of a certain price per pound is divided between the producer and the smelting company, must contribute largely to the treasury of the company. Since the middle of 1907 the depreciation in the value of metals has offset some of the gain previously realized. 4. Increase in the amount of ore smelted on the copper basis, which is more profitable than the lead basis. 5. Increase in earnings of subsidiary companies, such as the steamship company. 6. Earnings from investments of surplus, *e.g.*, the preferred stock of the American Smelters Securities Company. 7. Profits from investments, *e.g.*, the sale of a portion of its holding of the stock of the United Lead Company, carried into earnings for the year ending April 30, 1907.

The position of the smelting company being so strong in many respects, and the surplus which it carries being so large, the company may be forgiven for not writing off anything for amortization of its plants. As I have previously pointed out, the outlay made on account of extraordinary improvements is of the nature of an amortization account, but the amount expended so far in this way is of doubtful sufficiency. The smelteries and refineries now owned by the company must be worth in the neighborhood of $15,000,000, *i.e.*, it would cost that amount to replace them. The average amount expended for extraordinary improvements during the five years ending with April 30, 1907, was a little less than $750,000 per annum, which is only 5 per cent. of the physical value of the plants. This, it seems to me, is an insufficient allowance for amortization.

According to the statement filed by the company in the New York Stock Exchange, in January, 1909, its smelteries and refineries were the following:

SMELTERIES

Place	Plant	Furnaces	Annual capacity
Denver, Colo	Globe	7	322,000
Pueblo, Colo	Pueblo	7	328,000
Pueblo, Colo	Eilers	6	295,000
Durango, Colo	Durango	4	146,000
Leadville, Colo	Arkansas Valley	10	509,000
Salt Lake, Utah	Murray	8	523,000
East Helena, Mont	East Helena	4	235,000
Omaha, Neb	Omaha	2	82,000
Chicago, Ill	National	2	60,000
Maurer, N. J	Perth Amboy	3	140,000
El Paso, Tex	El Paso	10	492,000
Monterey, Mex	Monterey	10	460,000
Aguascalientes, Mex	Aguascalientes	10	720,000
Chihuahua, Mex	Chihuahua	3	153,000
		86	4,465,000

REFINERIES

Place	Plant	Lead, tons	Copper, tons	Gold and silver, oz.
Omaha	Omaha	156,000	....	36,000
Chicago	National	84,000	....	16,400,000
Maurer	Perth Amboy	66,000	66,000	36,000,000

The annual product of the refineries is about as follows: gold, 1,250,000 oz.; silver, 66,000,000 oz.; lead, 225,000 tons; copper, 66,000 tons.

CHAPTER XXIII

ZINC STATISTICS

Zinc.—A resumé of the progress of the zinc business of the United States in recent years, covering the war period, is obtained from the following statistics by W. R. Ingalls, *Engineering and Mining Journal*, May 31, 1919:

Production of Spelter
(In Tons of 2000 lb.)
By Ore Smelters Only

	1914	1915	1916	1917	1918
Arkansas	....	....	7,637	25,701	26,750
Colorado	8,152	8,984	8,908	7,735	3,897
Illinois	130,587	161,665	181,495	176,071	141,808
Missouri-Kansas	53,424	111,052	154,396	86,505	31,834
Oklahoma	92,467	111,405	169,064	204,587	143,371
Electrolytic	....	....	10,963	27,245	38,885
East and others (*a*)	85,682	114,036	147,555	154,567	138,805
Totals	370,312	507,142	680,018	682,411	525,350

(*a*) Includes Anaconda and other electrolytic production in 1915.

Statistics of Spelter-Sulphuric Acid Works
(In tons of 2000 lb.)

	1914	1915	1916	1917	1918
Ore received	434,666	614,565	752,021	779,941	485,276
Spelter produced	196,529	244,252	293,525	313,433	217,134
Sulphuric acid, basis 60 deg.	355,424	475,740	683,514	817,573	636,149

From these totals it appears that the recovery of spelter from the ores smelted averaged about 43 per cent. in 1914, 40 per cent. in 1915, 38 per cent. in 1916, 43 per cent. in 1917 and 46 per cent. in 1918. This indicates that in years of slacker demand higher grades are smelted, lower grades being used only during periods of sharper demand. We may conclude that the grade of ore smelted under average conditions yields from 850 to 900 lb. spelter and if the recovery averages 85 per cent., the gross content is from 50 to 55 per cent. Such grades of course can only be obtained by concentrating; some selected, hand picked ores no doubt are shipped in small lots, especially carbonates and silicates, but the

RECEIPTS OF ZINC ORE

(In tons of 2000 lb. This table includes the receipts of ore by the smelters only and does not include the production of ore exported or what was taken by the electrolytic producers or by the manufacturers of zinc oxide.)

State	1913	1914	1915	1916	1917	1918
Arizona	9,347	6,357	14,718	17,243	14,837	1,962
Arkansas	1,500	1,737	7,017	12,854	20,225	(c)
California	6,796	8,827	27,445	41,291	12,444	5,351
Colorado	220,166	164,739	148,359	194,418	184,304	82,995
Idaho	31,835	57,001	78,767	104,575	86,172	62,109
Kentucky	441	434	1,863	2,460	2,019	799
Missouri-Kansas	280,000	247,723	278,099	369,397	301,809	(c)
Missouri-Kansas-Oklahoma-Arkansas	(d)	(d)	(d)	(d)	(d)	476,954
Montana	91,257	125,663	200,528	233,645	171,904	152,905
Nevada	22,313	20,447	24,949	51,670	35,045	19,733
New Mexico	14,593	15,369	37,042	35,734	16,353	13,206
Oklahoma	23,500	26,247	25,231	42,799	153,035	(c)
Tennessee	8,297	18,708	38,527	43,309	38,488	45,924
Utah	27,073	20,322	21,535	43,240	21,381	14,758
Wisconsin (a)	89,662	74,311	90,128	91,561	137,248	123,506
Others and undistributed	57,241	57,936	122,490	111,273	192,393	98,870
Totals	884,012	845,821	1,116,698	1,395,4569	1,387,657	1,099,072
Mexico	19,965	16,414	49,171	142,687	135,368	49,532
Canada	6,012	10,532	14,000	31,877	21.502	14,502
Australia	....	....	68,448	134,464	37,031	618
Other foreign	....	....	9,211	73,394	31,714	2,373
Grand totals (b)	909,998(b)	872,767	1,257,528	1,777,891	1,613,272	1,166,097

(a) Including Illinois and Iowa. (b) In addition to the ore reported from Canada and Mexico, zinc smelters received a few thousand tons from Europe and Eastern Siberia in 1913. (c) See "Missouri-Kansas-Oklahoma-Arkansas." (d) See under separate states.

grand total of such shipments must be small and their effect is to reduce the average grade used at the smelteries. It also appears that nearly, or quite, a ton of sulphuric acid may be obtained from a ton of such ore, although presumably the purer sulphides are selected for this purpose.

Zinc Smelting.—It will be seen from the tables that between a third and a half of the spelter of the United States is smelted in Oklahoma and Kansas. Natural gas is the fuel and the occurrence of it is the sole reason of existence for the smelting industry in that region. There are three types of zinc smelting, or producing, plants:

1. The gas fired retort plants of Oklahoma which live on the advantages of cheap construction and cheap fuel, and produce spelter only.

2. The coal fired retort plants in the central industrial field of Illinois and Pennsylvania. These establishments are much more costly for construction, less economical for zinc smelting alone, but have the advantages of a more pemanent fuel supply and better facilities for distribution. The last factor enables them to engage in the production of sulphuric acid which is used largely in galvanizing iron at the neighboring steel plants, but is also the chief base of the chemical industry.

3. Electrolytic zinc plants, the chief of which is that of the Anaconda Copper Co. at Great Falls, Montana. The *sine qua non* of this operation is cheap power. A significant hint of the competitive strength of this process is contained in the fact that the great Anaconda plant was shut down in 1919.

1. Oklahoma Plants—Pre-war Conditions

It takes about 65,000 cubic feet of natural gas to treat a ton of sulphide ore. When this gas can be obtained for 7 cents a thousand cubic feet, or less, it becomes a desirable basis for zinc smelting. When gas can be obtained for 4 cents a thousand the advantage is very marked, not so much in the cost of operating as in that of constructing this kind of a plant. Thus a given margin of profit on the ore makes a much more handsome return on the capital invested than is the case with plants based on coal, which cost three or four times as much. It is confessedly a temporary and migratory business which becomes unprofitable when the available supply of gas runs short, or goes up in price, but if the operation will last five years with gas costing say 5 cents a thousand, the smelter will pay for itself; and so long as these opportunities recur it will continue to be a good business to build cheap plants at points where sufficient gas may happen to be found. How long such points may continue to be discovered is uncertain but the area in which they may occur is very considerable and I do not imagine that the end is yet very near. The following illustration of the capital required to install and conduct such operations throws light on the subject.

Four plants in Oklahoma had up to the end of 1918 a fixed capital expenditure of about	$3,000,000
The working capital at that date was about	3,000,000
	6,000,000

The maximum capacity was 380,000 tons of ore per year, so that the fixed capital per ton was about $8. In 1918 the actual tonnage was less than half of the maximum, but the working capital was the amount stated, say $17 per ton; from which we may conclude that the minimum capital required, fixed and current, is about $25 per annual ton; but when the output is curtailed it rises as high as $33 a ton. Perhaps it will average about $30. The operating cost was about $9.35 per ton of ore in 1912 and about $22 a ton in 1919. If we neglect the latter figure as one belonging to a period of economic uncertainty and return to the more secure proportion of things that existed before the war, we shall have to reduce to some extent the estimate of capital required, especially the working capital, nearly in proportion to the operating cost. It must

be remembered that although the ground-work of fixed investment of all these enterprises existed before the war the working capital is proportional both to the cost of operating and to the price of the product, which determines the amount of money required to buy ore and hold it until the contents are disposed of. Thus in 1912 (a year selected because the price of spelter was very close to the average), the figures were about as follows:

Tons treated	100,000
Fixed capital	$900,000
Working capital	$600,000
Number of retorts	12,000
Cost fixed capital per retort	$75.00
Cost total capital per ton ore treated	15.00
Operating cost	9.35
Interest on capital	0.90
Amortization of fixed capital in 10 years	0.60
Total estimated cost	$10.85
Operating profit	4.99
Actual profit as per estimated costs	3.50

Operating return on total capital about 33 per cent.

Assuming that these were the average financial and operating conditions on the ground and that the average smelting margin was determined by competition, we arrive at certain conclusions as to the value of zinc-ore.

Average price for year	5.66 cents
Smelters margin	$14.35
Loss in smelting 130 pounds at 5.66	7.36
Total margin and losses on the ground	21.71

Other deductions would be for freight and these would be determined partly by the grade of the ore and partly by the distance between the mine and the smelter. Assuming a standard Joplin ore running 60 per cent. zinc, the freight items would be about as follows:

Freight on 1070 pounds to St. Louis	$1.61
Freight on ore to smelter and loading	2.50
Grand total of deductions about	$25.80
Value of zinc in ore, 1200 lb. at 5.66	68.00
Margin to miner	$42.20

As a matter of fact the margin to the miner thus calculated is very close to the price paid for ore in Joplin for the period in question.

ZINC SMELTING CAPACITY, AND CAPITAL EXPENDITURE AT SPELTER PLANTS

	1 Oklahoma	2 Oklahoma	3 Oklahoma	4 Pennsylvania	5 Oklahoma	Total or Average
Year erected	1907	(a)1907	(b)1910	1913	1916	
Capital expenditure at end of 1916	$613,950.44	$128,071.26	(c)$755,696.87	(e)1,758,900.00	$882,702.93	
1917	695,851.28	141,660.54	770,653.57	(e)2,053,300.00	874,036.21	
1918	734,199.62	142,653.92	778,234.17	(f)2,052,658.84	890,209.92	4,597,956.47
Capital expenditure at end of 1918, per ton of maximum ore capacity (as below)	16.60	4.32	3.56	34.41	9.74	10.30
Working capital on hand at end of 1918:						
Current assets	763,291.67	269,173.56	−23,362.64	1,781,781.93	867,848.08	
Deferred assets	223,594.67	10,095.62	656,137.93	201,054.08	73,940.56	
Total working assets at end of 1918	986,886.34	279,269.18	632,775.29	1,982,836.01	941,788.64	4,823,555.46
Working capital per ton of maximum ore capacity (as below)	$22.31	$8.47	$2.90	$33.23	$10.30	$10.30
Tonnage treated in 1918	33,298	29,378	(g)14,300	(h)35,887	68,137	181,000
Furnace-days operated on ore (i)	4,945	3,902	1,626	3,513	6,529	20,515
Tons per furnace-day	6.733	7.529	8.795	10.215	10.436	8.823
Maximum available furnace-days per year	6,570	4,380	24,820	5,840	8,760	50,370
Maximum ore capacity, tons per year	44,236	32,977	218,292	59,656	91,419	446,580

(a) Purchased in 1910. (b) Constructed largely of second-hand material. (c) At June 30, 1916. (e) Estimated. (f) Spelter plant only. (g) 5 months only. (h) As delivered to spelter furnaces, consisting partly of calcined ore from acid roasting furnace. (i) Not including redistilling.

The following tables show the production of the United States and of the world.

PRODUCTION OF ZINC IN EUROPE AND AMERICA
(In Metric Tons)

Year	Austria	Belgium	France	Germany	Holland	Italy	Russia	Spain	United Kingdom	United States	Total
1896	6,888	113,361	45,585	153,082	4,770	Nil	6,257	6,133	25,278	70,432	421,786
1897	6,236	116,067	38,067	150,739	6,600	250	5,868	6,244	23,805	91,070	444,946
1898	7,302	119,067	37,155	154,867	6,700	250	5,664	6,031	28,387	103,514	468,937
1899	7,192	122,843	39,274	153,155	6,235	251	6,331	6,184	32,322	117,644	491,331
1900	6,742	119,315	36,305	155,799	6,845	547	5,693	5,611	30,207	111,794	465,438
1901	7,558	127,170	37,600	166,283	7,855	511	6,090	5,354	29,877	127,751	516,049
1902	8,309	124,780	36,300	174,927	9,910	485	8,280	5,569	40,244	142,552	552,356
1903	8,949	131,740	37,416	182,548	11,515	126	9,901	5,134	44,110	143,792	569,971
1904	9,159	137,323	41,600	193,058	12,895	189	10,607	5,887	46,218	164,921	621,857
1905	9,204	142,555	43,200	198,208	13,550	5	7,520	6,184	50,125	183,014	653,565
1906	10,711	148,035	46,536	205,691	14,650	69	9,610	6,209	52,587	204,548	698,646
1907	11,359	154,492	49,733	208,195	14,990	....	9,738	(c)6,000	55,595	226,398	736,500
1908	14,224	165,018	49,800	216,874	17,255	....	9,753	(c)6,018	54,472	190,933	724,347

World's Production of Spelter, 1910–1916, in Short Tons

Country	1910	1911	1912	1913	1914	1915	1916
Australia	560	1,904	2,531	4,105	5,616	5,300	5,700
Austria	14,666	18,602	21,609	23,928	....	....	....
Belgium	190,233	215,050	220,678	217,928	160,849	56,940	25,273
Canada	....	....	....	....	....	....	*a* 2,974
France	*b* 54,456	*b* 63,810	*b* 71,669	*b* 71,672	....	....	....
Germany	251,046	276,008	298,794	312,075	....	....	....
Great Britain	69,531	73,806	63,860	65,197	*c* 56,000	*c* 50,000	*c* 67,000
Holland	23,121	25,059	26,380	26,811	18,098	12,243	....
Japan	....	....	....	....	6,554	23,421	42,899
Norway	....	7,363	8,959	10,237	*c* 21,000	*c* 28,000	*c* 36,000
Russia	9,514	10,952	9,659	8,389	6,900	2,300	1,400
Spain	10,735	6,981	7,874	6,617	12,944	8,497	9,395
Sweden	....	....	....	....	2,535	9,466	11,020
United States	269,184	286,526	338,806	346,676	353,049	489,519	667,456
	893,046	986,061	1,070,045	1,093,635	....	....	....
United States percentage of world's production	30.1	29.1	31.7	31.7	....	....	....

a Mineral production of Canada, 1917, Canada Dept. Mines, 1919.
b Obtained by subtracting Spanish production from Metallgesellschaft total for France and Spain.
c Quin's Metal Handbook and Statistics.

The following table should be noted with caution. It is probable that the zinc in the "zinc-lead" and "other" ores, while no doubt recoverable, is very little utilized. It is interesting because it shows the extent to which zinc may be obtained as a by-product.

Zinc smelteries in the United States are distributed as follows: Electrolytic plants, Montana 1, Utah 1, California 1, Iowa 1, Maryland 1—total 5.

Retort plants: Arkansas 3, Colorado 1, Illinois 11, Kansas 17, Missouri 3, Oklahoma 14, Pennsylvania 3, West Virginia 4, Total 56. Of this 13, chiefly in Illinois, Pennsylvania, and West Virginia operate sulphuric acid plants.

MINE PRODUCTION OF ZINC IN THE UNITED STATES IN 1916

State	Zinc ore			Zinc-lead ore			All other ore (short tons)		Total (short tons)	
	Crude ore (short tons)	Recoverable zinc content		Crude ore (short tons)	Recoverable zinc content		Crude ore	Recoverable zinc content	Crude ore	Recoverable zinc content
		Quantity (short tons)	Percentage		Quantity (short tons)	Percentage				
Arizona	52,659	5,154	9.8	55,956	3,972	7.1	16,925,195	713	17,033,810	9,839
Arkansas	249,000	6,815	2.7	....	....	....	....	......	249,000	6,815
California	29,079	3,485	12.0	1,816	39	2.2	3,156,747	4,104	3,187,642	7,628
Colorado	151,497	26,437	17.4	291,489	37,006	12.7	2,254,257	3,700	2,697,243	67,143
Idaho	23,158	5,651	25.3	1,136,553	37,602	3.3	1,558,334	......	2,718,045	43,25[illegible]
Illinois	*a* 288,100	3,404	1.4	....	....	....	....	......	*a* 288,100	3,404
Iowa	*b* 1,000	21	2.1	....	....	....	....	......	*b* 1,000	21
Kansas	774,400	12,448	1.8	....	....	....	....	......	774,400	12,448
Kentucky	*b* 11,000	1,096	10.0	....	....	....	....	......	*a* 11,000	1,096
Missouri	13,196,400	155,960	1.1	....	....	....	5,467,624	......	18,664,024	155,960
Montana	388,380	33,654	8.6	702,885	79,444	11.3	6,769,160	1,9[illegible]2	7,860,425	114,630
Nevada	31,886	9,945	31.2	33,303	6,277	18.8	5,875,976	......	5,941,165	16,222
New Hampshire	....	....	....	3,500	36	10.2	....	......	3,500	36
New Jersey	712,464	110,698	15.5	....	....	....	....	......	712,464	110,698
New Mexico	*c* 137,696	18,285	13.3	....	....	....	3,733,254	......	3,870,950	18,285
New York	40,800	4,507	11.0	....	....	....	....	......	40,800	4,507
Oklahoma	1,406,900	28,754	2.0	....	....	....	....	......	1,406,900	28,754
Tennessee	702,326	26,428	3.7	....	....	....	482,495	......	1,184,821	26,428
Texas	443	116	26.2	....	....	....	52,589	......	53,032	116
Utah	18,400	4,433	24.1	461,866	10,353	2.2	13,440,377	......	13,920,643	14,786
Virginia	4,480	959	21.4	30,961	1,317	4.2	3,821	......	39,262	2,276
Washington	154	54	35.0	17,039	793	4.6	147,805	......	164,998	847
Wisconsin	3,066,500	56,803	2.3	....	....	....	....	......	3,066,500	56,803
	21,286,722	514,707	2.4	2,735,3[illegible]8	176,839	[illegible].5	59,867,634	10,449	83,889,724	701,995
Percentage of total recoverable zinc derived from each kind of ore	....	73.3	....	....	25.0	....	....	1.5	....	100 0

a Exclusive of fluorspar ore. *b* Estimate. *c* Includes zinc-lead ore.

CHAPTER XXIV

ZINC MINING

SOUTHWEST MISSOURI—MIAMI DISTRICT—WISCONSIN IN 1908—BUTTE AND SUPERIOR—INTERSTATE-CALLAHAN—CONCLUSIONS ON ZINC.

Zinc Mining Statements.—I have not been able to secure many statements by zinc-mining companies showing the same outline of the business that can be secured in the case of most other mining enterprises. Through a certain familiarity with the business, however, I am able to supply a perspective of results in some of the more important fields in the following sketches of zinc-mining operations of Joplin and of Wisconsin. At the end of the chapter will be found some generalized statements of the cost of mining ores of certain assumed grades in these districts. As a matter of fact there is no such thing as a complete zinc-mining business in the United States outside the operations of the New Jersey Zinc Company, which is apparently one of the most secretive of all corporations. The product in general is obtained through the combined, but more or less disjointed, efforts of leasers and custom smelters.

THE SOUTHWEST MISSOURI ZINC DISTRICT IN 1908

This district produces 60 per cent. of the spelter of the United States, and, therefore, bears nearly the same relation to the zinc business as Lake Superior mines bear to the iron business of the country. Perhaps no other district of equal importance is so little understood by outside mining people.

The Joplin field is a very extensive one, more or less ore having been mined over an area of perhaps 2000 sq. m., but within this extensive field by far the greater part of the production has come from three or four localities. Of these the most important may be called the Webb City zone, which is said to have produced about one-half of the entire output of the field. In the immediate vicinity of the city of Joplin, there are very extensive mineralized zones extending in a northwest and south east direction. A third place that has produced extensively is in the neighborhood of Galena, Kansas. I shall attempt a general description of these orebodies by using as an example the great Webb City zone.

This productive area extends from Oronogo on the northwest to Porto Rico and Duenweg on the southeast, a distance of ten miles. For

SHIPMENTS OF ORE FROM THE JOPLIN DISTRICT

Year	Zinc ore	Lead ore	Year	Zinc ore	Lead ore
1895	144,487	31,294	1902	262,545	31,625
1896	155,333	27,721	1903	234,873	28,656
1897	177,976	30,105	1904	267,240	34,362
1898	234,455	26,687	1905	252,435	31,679
1899	255,088	23,888	1906	278,930	39,189
1900	248,446	29,132	1907	286,589	41,742
1901	258,306	35,177	1908	259,609	38,532

PRODUCTION OF ZINC IN NEW SOUTH WALES
(IN TONS OF 2240 LB.)

	1903	1904	1905	1906	1907	1908
Spelter	286	299	544	1,008	984	1,065
Zinc in ore exported	14,625	22,318	30,637	33,427	76,645	113,853

this distance the average width of the zone is perhaps three-quarters of a mile, though it widens at one or two places to a mile and a half and narrows at other places to a quarter of a mile. In a rough way, I estimate the productive ground at 4800 acres. It would not be inaccurate to describe this entire tract as a continuous orebody, although it shows great irregularities. The total production of this zone has been approximately 3,000,000 tons of zinc and lead ore, derived from mining and milling 75,000,000 tons of rock. The value actually realized has been about $90,000,000, but at present prices the amount would be much greater. The production of the zone for 1907 was 109,229 tons zinc ore worth $5,000,000 and 24,336 tons lead ore worth $1,700,000, approximately, making a total value on the ground of $6,700,000. The spelter realized from this production may be estimated at 55,000 tons, worth in St. Louis $6,390,000. The pig lead realized may be estimated at 19,000 tons, worth in St. Louis $1,985,000. The average price of spelter was 5.812 cents at St. Louis, and of lead 5.225 cents. On these prices the average yield to the miner was $45.23 for zinc ore and $68.73 for lead ore.

Geology of the Joplin District at Large.—The rocks in which the ore occurs constitute a flat-lying formation of chert and limestone about 250 ft. thick. At the bottom of the formation is a persistent bed of flint about 20 ft. thick, called the Grand Falls chert. Above this is limestone containing many layers and nodules of flint. Originally this cherty limestone formation was all covered by a stratum of black shale, which occasionally contains a little coal. The greater part of this shale has been removed by erosion, but certain portions of it still remain in

the form of long strips filling trough-like depressions in the underlying limestone.

The orebodies of the region are all contiguous to these areas of depressed shale, occurring either under or along the sides of the shale troughs. These troughs of shale are called, by the way, "soapstone bars." The explanation which I believe to be the true one of the occurrence, both of the shale troughs and of the ore, is as follows:

The limestone, along certain lines (of an origin not at present explicable), was dissolved out while the shale formation still overlaid the entire region. The caverns formed by this dissolution finally became so large that they caved in, allowing the over-lying shale to settle down into the pits thus formed to a depth of from a few feet to as much as 150 ft. below the surface of the cherty limestone formation. The dissolution of the limestone did not affect the chert beds. These were broken up during the subsidence caused by the disappearance of the lime. The result was that underneath and along the sides of the shale filling of the troughs there were great quantities of broken flint mixed with mud derived from the soft overlying shale. There were also masses of limestone, of all sizes, remaining on the sides and even in the bottom of the troughs. The limestone remnants increase quantity as you go from the center of the trough until finally you reach the solid unaffected masses.

Ore has been deposited in the brecciated, or disturbed mass of flint and limestone boulders and clay occupying the space between the depressed shale in the center of the trough and the unaltered formation at its bottom and sides. The ore was brought in by surface waters. Naturally the deposition of ore was not uniform. It is supposed that the organic matter in the shale was the precipitating agent which caused the deposition of zinc and lead sulphates picked up by the surface waters during the process of the erosion of the Ozark plateau to the southeast. At any rate the ore is found in exceedingly irregular bodies in the broken ground along the troughs of shale, or "soapstone bars."

Naturally, channels of dissolution such as those described as causing the troughs would be of varying extent and depth. This is the case. In some of the larger channels the limestone has been removed quite to the bottom of the cherty limestone formation and the broken ground extends down to the basal member—the Grand Falls chert. This chert is a brittle stratum of flint containing innumerable crevices so that it serves as a ready channel for the circulation of water. On this account much ore has been deposited in it. It is called the "sheet ground." This sheet-ground ore, while of exactly the same composition and origin as the other ore, is distinguished from it notably in several respects. Instead of being in a mass of broken ground along the "soapstone bars" it occurs under the solid original limestone masses. Instead of being in

a shapeless irregular mass, it forms a regular flat bed, like a seam of coal. Laterally, its extent is variable, as also is its richness, but the mineralization is pretty uniform over extensive areas, often as much as 2000 ft. wide. It must never be forgotten, however, that the sheet ground is always attached to the *loci* of mineralization—the "soap stone bars." It forms extensive shoots under the limestone bordering the deepest and most strongly mineralized bars or channels. If often extends 1000 ft. from a bar, very rarely over 2000 ft.

Practically all of the successful sheet-ground mining to date has been confined to the great Webb City ore-channel, between Oronogo and Porto Rico. It is generally believed that the sheet ground yields about 3 per cent. of the rock mined in zinc or lead ore. The zinc ore obtained averages not far from 60 per cent. zinc; the lead ore about 80 per cent. lead. The ore is obtained by crushing and washing in concentrating mills, which save about 60 per cent. of the zinc and 90 per cent. of the lead actually contained in the rock. The total saving approximates 66⅔ per cent.

Exploration.—Practically the only method now employed in searching for ore is churn filling. The irregular deposits along the soapstone bars are apt to be quite narrow. The vertical extent is often greater than the width. Consequently, in looking for such orebodies it is necessary to drill holes pretty close together. An experienced driller can form a good idea from the kind of ground he encounters of what the chances are of finding ore. If he finds a little ore and open ground, that is, broken rudely stratified material, he will place his following holes not over 50 ft. from the first until he discovers pay ore. Then he will endeavor to follow the ore by drilling along the course of the bar. Where the bars are small and irregular, it is often necessary to drill as many as three or four holes to the acre to explore a tract thoroughly. Since the drilling costs an average of 80 to 90 cents per foot, and the holes will average about 175 ft. deep, we may place the cost of exploring such a tract roughly at $500 per acre.

In the sheet ground no such amount of drilling is necessary. On account of the much greater uniformity of the deposits it is often possible to explore the ground satisfactorily with only one hole to every two acres. Holes to explore this ground are drilled more than 200 ft. and the cost per hole will approximate $200. The actual cost per acre for exploring this ground is probably less than $100, but I think it should properly be about $200.

It is the almost universal custom to appraise the value of the ore only by the eye. The cuttings from the drill come out in the form of coarse angular sand which the driller washes in a bucket of water, and simply forms a judgment as to whether the sand contains pay ores or not. If the cuttings show only small amounts of ore, not enough

in his judgment to pay for mining, he records "a few shines of jack or lead." If he thinks the ground doubtful he writes—"shines" or "good lead," or both.

Mining Methods.—The mining of this ore will be readily understood from the above description of its occurrence. Owing to the shallowness of the deposits there is no occasion whatever for large expensive shafts. As the extreme depth is only 250 ft.; and the average depth in mining perhaps less than 175 ft., it is evident that a single-compartment shaft, except in the unusual contingency of encountering a very large amount of water, can be sunk very cheaply. It is probable that the average shaft of the Joplin district does not cost more than $4000. Hence it is cheaper to open up the ground by numerous shafts rather than by extensive openings underground. It will also be evident that aside from the question of first cost the tramming of ore is cheaper on the surface than underground.

The effect of these considerations is that the accepted method of operating in the district is to have one mill supplied with ore from several shafts, the ore being transported to the mill by inclined tramways.

The hoisting methods of the district are unique and, considering the conditions, exceedingly satisfactory. The ore is shoveled into buckets locally called "cans" which hold about 800 lb. each. These cans are placed upon small trucks underground and run to the shafts, where they are attached to the hoisting rope by a man called the "tub-hooker." The hoist is placed in a derrick or headframe vertically above the shaft, the rope passing over the sheave a few feet above the engine. The hoist man pulls the bucket up so that the bottom of it is slightly above his head. He then attaches to the bottom of the bucket a hook which, when the bucket is again lowered, dumps it into a bin. To do this, hoist his empty bucket back to position, detach the hook, and lower again, is in the hands of an expert hoistman, a matter of only a couple of seconds. In this manner it is possible to average 400 cans per shift, or 160 tons. Only two men are employed, whose combined wages are approximately $5 per day. The hoist itself costs $250. The derrick in which the hoisting is done, together with the bin ore, costs $600 more. It is evident that this method of operating, while having the appearance of crudity, is exceedingly effective and cheap. The actual cost is probably not over 5 cents per ton hoisted.

The mining underground involves the usual requirements of selecting the ground so as to mine out the best of the ore without leaving too much in the pillars and without making the openings too dangerous. In the "upper ground" irregular deposits this selection opens the field for the exercise of skill. In the sheet-ground deposits the work is far more regular and certain. As a general statement, the advantages of the upper deposits in the way of richer ores and softer ground are nearly, if not

quite, counterbalanced in favor of the sheet ground by the greater uniformity and persistence of the latter. There is really very little difference in the methods employed in the two kinds of mines. In the upper ground the ore is taken from large irregular chambers and in the sheet ground from flat deposits from 8 to 20 ft. thick that are as regular over considerable areas as a seam of coal. The only differences in mining between the two kinds of mines are of an unimportant nature which will be readily understood from the above description, and need not be explained.

Milling Methods.—The visitor from outside districts is apt to be very much surprised at the crudity of the milling methods employed, and many an engineer has discovered what he believed to be a field for vast improvement by introducing better methods. Thus far nothing whatever has come of such attempts. They have usually been based upon some radical misapprehension of the conditions.

The Joplin mills confessedly only extract about 60 per cent. of the zinc ore. The proportion varies greatly at different mines. The variation, however, is not generally due to the mill practice, but to the character of the ore. The mills are suited to save only the free ore which can be easily separated from the gangue by rather coarse crushing. The remaining zinc which is enclosed in small particles in a secondary growth of flint cannot be saved except by much finer grinding and much more expensive methods for which the resulting ore extracted will not pay.

The ordinary mill consists of no more than three large Cooley jigs supplemented by one or two Wilfley tables. The Cooley jigs are of the Harz type, but contain usually from five to seven cells. The ore after being reduced to about one-half inch is next passed to the rougher jig, which catches some of the coarse lead and makes a rough concentration of the zinc ore. This is drawn as a middling product from the rougher and, after being passed over a second pair of rolls, goes to a second jig called the "cleaner." The tailings from the cleaner jig are sometimes passed over a third or smaller jig for further treatment and a certain proportion of finer material is settled out for treatment in one or two Wilfley tables. The ordinary mill costs from $10,000 to $20,000 and has a capacity of about 15 tons an hour. The largest mills in the district have cost about $50,000 and have a capacity of 35 tons an hour.

Losses in Mining.—It must be remembered that the mining of zinc ore was first begun as an incident to lead mining, which was done at or near the surface. At first the zinc ore was sold usually at very low prices. It was cleaned on hand jigs, but later cheap and crude mills were built.

As the lead was found in small irregular patches, at or near the surface, there was no inducement to mine it on a large scale. One or two miners would work at it and pay royalties to the farmers who owned the land. Since two men could not work much land, there was no demand for

leases of more than a very few acres. As lead mining gradually changed into zinc mining the small leases continued and the small mills were only expected to handle the richest pockets of "jack." In this way the business has built itself up in ever-increasing volume as a multitude of small leases. The system has all the faults that might be expected of it, but it was the one which the circumstances demanded. That it is attended by frightful losses will appear from the following summary of operating results.

Take 100 tons of ore containing 5 per cent. metallic zinc in the ground, we have the following approximate statement:

Costs and Losses on Zinc Ore

	Costs	Losses	Total
Spelter value 100 tons 5 per cent. ore at 5 cents, St. Louis	....	....	$500.00
Loss in mining, 10 per cent	....	$50.00	
Mining, 90 tons at $1.05	$94.50		
Loss in milling, 40 per cent	....	180.00	
Milling 70 tons at $0.25	22.50		
Loss in smelting, 12 per cent	....	35.10	
Smelting and amortization	54.00		
Transportation	9.15		
Total	$180.65	$265.10	$345.75
Approximate profit	....	....	$54.25

This shows a recovery by mining of $450; by milling of $270; by smelting of $234.90. The approximate costs are 36.1 per cent. of the total value; the losses, 53 per cent.; the profit, 10.9 per cent. The profit on recovered value is 23 per cent., and this profit is divided as follows: Smelter, $14.25, or 26 per cent.; royalty, 15 per cent., $23.60, or 43 per cent.; mines, $17.15, or 31 per cent. of the total profit.

Joplin Cost Statements.—The cost statements of the Joplin districts are open to a good deal of uncertainty, on account of the lack of accurate information concerning the tonnage handled. The accompanying statement of the Grace Zinc Company illustrates the point. The "cans hoisted" refers in the local vocabulary to buckets, the greater portion of which are assumed to hold 1000 lb. As a matter of fact, it is known that they do not; some operators estimate that they hold 900 and others 800 lb. On either of these two assumptions the tonnage would be much greater than that taken as the basis for the cost statement which is only 625 lb. per bucket. This tonnage estimate is based on the tonnage content of cars holding from 1½ to 2½ tons in which the ore is hoisted to the mill. A considerable amount is rejected as waste. If we were to assume that the cans contained 800 lb. each, our tonnage would be 156,000 and the costs, instead of totaling $1.41, would be reduced to $1.10. If the cans were estimated at 900 lb. each, the tonnage estimate would be almost

180,000, and the cost would fall to 95 cents. The low grade of ore, and particularly the method of leasing and mining which has been adopted, prevent the installation of devices by which a more accurate measure could be taken of the tonnage.

GRACE ZINC COMPANY

PRODUCTION AND COST STATEMENT APRIL 1, 1905, TO JAN. 1, 1908

Cans hoisted	390,346
Tons dirt milled	121,291
Tons mixed ore recovered	5,307

	Per ton dirt	Per ton concentrates	
Breaking ore	$0.40	$9.03	$47,939.43
Tramming	0.21	4.85	25,722.82
Hoisting	0.15	3.32	17,616.19
Pumping	0.10	2.27	12,050.81
Exploring	0.09	2.10	11,160.39
Timbering	....	0.09	452.18
Milling	0.23	5.33	28,304.19
General expense	0.15	3.56	18,870.34
Construction	0.08	1.74	9,248.40
Total	$1.41	$32.29	$171,364.75
Royalty paid			$38,957.55
Net value of ore			$221,230.21
Total expense			171,364.75
Net profit			$49,865.46

A more accurate statement of costs is based on the tonnage of concentrates produced. The amount of these is, of course, accurately determined. It is probable that the figures given in the accompanying statement give a fair idea of average costs for mining and milling in the Joplin district.

I have not made an estimate of the amortization charge, which should be made against such a plant as that from which the cost statement is taken. The actual cost of such a plant outside of the amounts covered by construction and exploring is probably not over $20,000. All renewals are covered in operating expense. Construction probably more than takes care of the plant itself. It is probable that a sum of $3000 a year in addition to the costs given would be an ample return on the actual plant investment. This would amount in the table to less than $8000, and would increase the total costs per ton of dirt to $1.49, and per ton of concentrates to $34.

Assuming the last figure to represent the complete mining and milling cost, and that a concentrate containing 60 per cent. zinc is smelted at a cost of $14 a ton, with a loss of 12 per cent., we find that 1056 lb. of spelter costs $48, or 4.54 cents per pound. While it is undoubtedly

true that some mines at all times, and most mines for short periods, can produce spelter cheaper, I believe that the above figure is a fair average.

Miami District, 1919

The above description of the Joplin field and its mining processes will still serve the purpose although superficially great changes have taken place. Nearly every mine in the tracts described is now worked out; but the production of the field is maintained. In 1916 the mines of the Webb City-Joplin tracts were still operating at high pressure under the influence of the great war boom in zinc of 1915. According to Siebenthal 13,196,000 tons were mined, yielding only 155,960 tons of spelter, 1.1 per cent.! With the wane of prices and the rise of costs such mines of course became hopelessly unprofitable.

But 25 miles to the southwest a new district, called the Miami, in Oklahoma sprang up like a mushroom. Mr. R. C. Allen has kindly given me the following facts about it: Geologically there is little difference from the tracts described above except that the ore, instead of lying under detached troughs of shale, is under the main outcrop of it, occurring as much as five miles back under the cover of this shale, which here is not only carbonaceous but oil bearing. It appears that the whole Joplin field has been mineralized by a migration of mineralized waters toward the northwestward during the slow weathering and erosion of the low dome of the Ozarks; the mass of which lies toward the southeast. The rocks composing this dome (see chapter on S. E. Missouri) are of lower Paleozoic age. The cherty Mississippian limestone perhaps was a general channel for waters which entered the ground at a higher level. Such waters flowing under some head forced their way along the pervious chert beds at the bottom of the limestone for some distance under the overlying impervious shale. But that formation was an effective barrier and the percolating waters were impounded under it. Perhaps a return flow was set up in places along the lower surface of the shale beds, or, perhaps in places fault fissures allowed the waters to escape through them. More probably, perhaps, such faults would crack up the brittle cherts of the Mississippian thus making an easy channel of circulation along which the mineralized waters might travel far; but the fissures would be entirely closed in the plastic clay shale. At any rate it is supposed that the carbonaceous material of the shales helped cause the solutions of zinc and lead sulphates to be precipitated as sulphides.

Although the mines of the Miami district, owing to its being entirely beneath the shale, are considerably deeper than those about Joplin, their extreme depth is only 380 feet. Exploration was conducted by churn drilling on an open prairie. The mines were opened like magic. At the beginning of 1916 not a mill was in the district; by the middle of

1919 there were 205 with a nominal capacity for treating 110,000 tons a day; but, owing to the slack demand for ore, only a small proportion of these were running. The total cost of all this development and equipment, all built of course under war conditions, was estimated at about $24,000,000. Up to January 1, 1919 these plants had operated as follows:

Tons rock treated	9,630,000
Concentrates produced	651,000
Recoverable zinc	275,000
Recoverable lead	68,000
Average yield, metallic zinc	2.85 per cent.
Average yield, metallic lead	0.7 per cent.

Thus the ores in this district are more than three times as rich as those about Joplin. The recovery in concentrates is about 6.8 per cent., *i.e.*, if those concentrates bring $40.00 a ton the crude ore milled yields $2.72. The average cost of operating is about $2.00, say $1.50 for mining and $0.50 for milling; equal to $30 per ton of concentrate.

But on the whole the business is patently unprofitable. It is impossible that the 205 mills can average more than 2000 tons of concentrates each per year. It is not probable that the average operating life even at that rate can be as high as 10 years; more likely it is about 5 years. At either of these rates the cost of capital is prohibitive. Even on a ten-year life it will be $9.00 a ton. Since nearly all these mines are leases they pay royalties averaging certainly not less than 15 per cent.; therefore the yield to the operator is only 85 per cent. We have then:

Operating costs	$30
Plant cost	9
Total	$39

To come out even this must be only 85 per cent. of the selling price, which then must be $46. This is a minimum which would yield no profit to the average operator under assumptions of life that are certainly not warranted. I doubt if this business would be as good as neutral at a price of $52.00 per ton of concentrates. At that price at least as many would lose money as would gain it. The district has been ridiculously over-equipped. I suppose two-thirds of the mills can only operate spasmodically.

Of course there are always some operators who are clever enough, or whose properties are good enough, to make money. Such men, I am told, count on an extraction of about 20,000 tons of concentrates per forty acre lot. The cost of development and equipment is about $150,000 equal to $7.50 per ton. If the crude ore is better than the average they may produce concentrates for an operating cost of say $20. With such a mine, allowing the royalty to be 15 per cent. and the price of ore $40, the cost and royalties would be about $34 and the profit, say $120,000,

or $3000 per acre. The return on the capital would be, perhaps, 16 per cent. But this is a meager prospect for a short lived investment plus the administrative effort and skill required to carry one of these enterprises through. I think we must suppose that the business offers no very striking rewards unless the concentrates will average $50.00 at least.

If this is true it follows that a fair price for the metals from this district, on the ground is nearly 5 cents a pound (average yield 1050) and to this must be added, under present conditions nearly 3 cents for transportation and smelting, bringing the total price required for the combined zinc and lead recoverable, to about 8 cents per pound.

Zinc Mining in Wisconsin, 1908

Wisconsin has been within the last few years second in the production of zinc in the United States. Its future is thought by many to be exceedingly promising, but I must confess to some doubts as to the ability of the district to maintain a large output for many years in succession. The district is in the extreme southwestern corner of the State.

The zinc ores are associated with iron in the form of marcasites, usually in almost equal quantities. It is impossible by ordinary methods of water concentration to separate this iron from the zinc. The separation must be accomplished electrically either by magnetic attraction or by static repulsion. The magnetic separators are cheap installations costing about $10,000 each for a capacity of some twenty tons of concentrates daily. The process consists of a very light roast which partially oxidizes and magnetizes the marcasite so that by passing the ore thus roasted by a group of magnets, the iron is taken out. This is the usual method employed in the district.

With the exception of the association of zinc with the iron there is no radical difference between the problem of mining in Wisconsin and in Missouri except that the orebodies have certain different characteristics which I shall presently explain. The mining and milling can be done in approximately the same way, although the costs in Wisconsin seem to average some 20 per cent. higher than in Missouri.

The Wisconsin orebodies fill partial openings in the limestone made by the subsidence of large prism-like masses in the bottom portion of the limestone. The limestone stratum in which the ore occurs is about 150 ft. thick, and is underlaid by a persistent bed of clay shale. It looks as if the limestone might have been dissolved out for a foot or two above the shale along certain channels to such an extent that finally a large irregular prism of limestone detached itself from the solid mass and fell down a distance of perhaps two feet. The result of this subsidence being that the interior of the prism is cracked up to a certain extent and certain openings are made along the top and sides. These openings have served for the deposition of the ores.

The openings thus formed in the cross-section have the shape of a rude arch, usually quite flat at the top, and breaking down in irregular steps along the sides. In the local phraseology, the ores deposited in the level at the top of the arch are called "flats," and those occurring along the sides are called "pitches." The slightly disturbed broken up interior of the prism is called the "core."

These orebodies have precisely the irregularities that one would expect from such an explanation of their origin. In some places the dissolution of the lime, or whatever it was that caused the subsidence, was more extensive than at other places; so that the prisms are both wider and higher in some places than in others. The high places take the shape of long elliptical cones. That is to say, that the roof slopes down both longitudinally and in cross-sections. In some cases these prismatic orebodies have been proved to have considerable presistence in length. The Empire and Enterprise mines have been worked on one run of ore for a total length of about half a mile, the greatest width being about 120 ft.

It remains to say that the mineralization of the prisms is irregular. Ore sometimes is found on both sides of the arch, but is generally of pay quality on one side only.

These orebodies seem to have an ordinary course of about N. 70° E., but sometimes they make an abrupt turn, and in one well-authenticated case the ore turned at right angles to its ordinary course, and ran for 350 ft. in a course of N. 20° W.

It is believed locally in Wisconsin that the runs of zinc ore will be found to be exceedingly presistent, not always following the same direction, but making occasional turns and then resuming their other course again. It seems to me likely that they will have a considerable degree of persistence, but that they will be persistently payable is a different matter. Very likely the large prisms that have been well mineralized and are payable will be found to be connected only by comparatively small and tortuous channels that will not pay for working them.

The Cost of Zinc Mining in Wisconsin.—The actual operating expenses in Wisconsin seem to be about the same or a little higher than in the Joplin field. The only reason for the increased cost is the smaller volume of ore that can be secured from any one shaft. It is usual to pay a royalty of 10 per cent. to the owners of the land.

Butte and Superior

This company has done the chief part of the mining on a great shoot of silicious zinc-silver ore which is spread for perhaps three quarters of a mile along one of the major fissure veins of Butte, Montana The western end of these ore-bodies has been the subject of apex litigation by virtue

of which, partly, the neighboring Elm Orlu Mining Co. is also an important mine.

It seems that this vein, called the Rainbow Lode, is an example of the zonal deposition of ores. At the surface it contained only silver-manganese ores. The large bodies of zinc sulphide came no nearer than 700 ft. to the present surface. They were not impoverished at the surface by leaching—they are all primary. What succeeds the zinc at greater depths is not known. Copper bearing veins, apparently of later age flank this lode on the south and, I believe, intersect it. It has been surmised that copper ores might occur in the Rainbow lode below the zinc, but no evidence of it is reported at the depth of 2050 ft.

The general results of zinc mining, the grade of crude ores and concentrates, scale of operations are shown in the following tables.

	Crude		Zinc concentrates			Smelter returns	Freight to smelter	Net return to mine	Profit
	Tons crude ore milled	Per cent. zinc	Tons	Per cent. zinc	Oz. silver				
1913	296,940	19.9	104,174	49.00	24.2	$3,526,660	$850,007	$2,676,652	$942,988
1914	327,210	18.6	101,411	53.16	25.4	4,037,674	799,259	3,238,414	1,417,127
1915	522,300	17.0	152,897	53.62	22.14	13,244,133	1,157,016	12,087,116	9,125,947
1916	627,370	15.5	171,747	52.88	21.54	14,625,321	1,483,770	13,141,551	8,873,445
1917	461,953	15.5	138,661	47.4	17.83	7,817,674	1,101,237	6,716,437	2,347,495
1918	468,814	15.9	135,533	51.2	20.03	6,922,803	1,007,558	5,915,244	714,798
Totals	2,704,587		804,433				$6,397,847		$23,421,800

Net Current and Working assets at end of period increase	$3,321,000
Dividends paid	16,571,510
Total dividends and increase of surplus about	19,900,000
Capital and other charges from profits about	3,500,000

These capital charges are clearly accounted for in the reports and consist of purchases of mining claims, additions to equipment and investments in stocks, bonds, etc. They are all of such a character as to be required in the course of the business and cannot be liquidated, therefore they must be added to the cost of production at the rate of approximate by $1.25 per ton milled.

Mining and Milling Costs
Per Ton Crude

	Mining	Milling	General	Depreciation	Total
1913	$3.09	$2.69	$0.07	$1.25	$ 7.10
1914	3.25	2.17	.22	1.25	6.89
1915	3.69	2.08	....	1.25	7.02
1916	4.79	2.14	....	1.25	8.18
1917	5.49	2.74	1.23	1.25	10.71
1918	7.59	2.95	.68	1.25	12.48

Commercial Results per Ton of Concentrate

	Price of spelter, cents per pound	Price silver per oz., cents	Total value	Smelter returns	Deductions
1913	5.6	60	$69.28	$33.90	$35.38
1914	5.08	55	67.75	40.00	27.75
1915	13.05	51	151.25	86.56	64.69
1916	12.63	66	147.70	85.17	62.53
1917	8.73	82	97.35	56.35	41.00
1918	7.76	100	99.45	51.78	47.67

	Freight	Cost of mining	Total costs and losses	Total profit	Profit per pound zinc recovered, cents
1913	$8.15	$21.04	$64.57	$4.71	0.6
1914	7.89	22.22	58.86	8.90	0.9
1915	7.56	23.95	96.20	55.05	5.8
1916	8.64	30.00	101.17	46.53	4.5
1917	7.94	35.64	84.58	12.77	1.8
1918	7.43	43.12	98.22	1.23	0.13

From this it appears that the cost of producing spelter for all costs, capital and operating, from this high grade ore were no less than 5 cents a pound for recovered zinc in 1913 and rose to 7.6 cents in 1918. The margin of profit except during the war boom has been consistently narrow. The real profits in 1918, after making sufficient allowance for depreciation, were almost nothing.

When we look at the high metallic contents of these ores, at the prices of 1918, it is rather surprising that there is so little profit. The crude ore contained, per ton:

6.33 ounces of silver at $1.00	$6.33
3 pounds copper at 24.7 cents	0.74
26 pounds lead at 7.1 cents	1.85
318 pounds zinc at 7.76 cents	24.67
Total apparent value	$33.59

There is no suspicion of poor management; the facts are much to the contrary. It is rather an example of the progressive dissipation of value in a complex ore in the various processes through which it must be taken. The cost of mining and milling consumes 37 per cent. The first losses are in milling by which 8 per cent. of the silver, 14 per cent. of the copper, 4 per cent. of the lead and 6 per cent. of the zinc, aggregating, about $2.10 per ton, are put into the tailings. In the next step 7.6 per cent. of the total value is consumed in freight. The zinc smelting saves the zinc only, the other metals are left as residues which must be smelted

over again. Here we have a terrific rejection at once; 13 per cent. of the zinc and nearly all of the other metals, say altogether about 30 per cent. of the value. The smelting margins (see zinc smelting) are about $28 per ton of concentrate equal to 25 per cent. of the total. Thus to sum up;

Mining, milling and depreciation account for	37.1 per cent.
Losses in milling	6.3 per cent.
Freight to smelter	7.6 per cent.
Smelter margins	25.0 per cent.
Loss in smelting	30.0 per cent.
Consumption of value on zinc basis only	106.0 per cent.

But a certain margin of profit is recovered by the sale of residues containing silver, copper and lead, and of a small amount of lead concentrate saved, so that the apparent loss of 106 per cent. is reduced to about 98 per cent.

These were the conditions of 1918. It is not to be expected that they are representative. Under the operating conditions the price of spelters was abnormally low. As an operating proposition the mine was never quite on its feet until 1914. To apply the operating results of that year to average prices, we get the following:

Value as before of zinc, copper, lead and silver in crude		$22.00
Cost mining and milling	$6.89	
Loss in milling	1.35	
Freight	2.30	
Smelter margins	4.64	
Loss in zinc smelting	2.15	17.33
Profit on zinc basis		$4.67

As before there would be considerable salvage in the residues, so that we may suppose the total profits would be about $5.50 equal to about 25 per cent. of the gross value in the ore.

It is interesting to note that the cost of mining on this lode is high, just as it is in the case of the copper mines of the same district; that the average of capital expenditures is about the same as in other mines of the same class for example the Bunker Hill-Sullivan; and that the rich ores of the west, carrying 15 to 20 per cent. zinc with a proportion of other valuable metals, are not after all invincible competitors for the zinc mines of the Mississippi Valley, which do well to average 4 per cent. in zinc and lead combined.

Consolidated Interstate-Callahan

This is the principal zinc mine of the Coeur d'Alene district. It occurs in a fissure vein on the west side of the Canyon Creek batholith

and is in all respects similar to the silver-lead veins of that district except that it occurs in the Pritchard formation which is more slaty than the overlying Burke and Revett formations. In the cost of mining and milling however this mine was never able to reach the low figures of some of the lead mines, because the vein is narrower. About \$5.50 per ton was about as a cost as was ever reached. It would now be \$9 to \$10 at least per ton of crude and that would mean about \$25.00 per ton of concentrates. The mine has been able to ship at the rate of some 70,000 tons of concentrates a year and made a great deal of money during the boom years 1915 and 1916, but ordinarily its margin of profit would be slender just as in the case of Butte and Superior. Its shipments and earnings were about two fifths those of the latter mine.

Conclusions on Zinc Mining

These analyses of the zinc industry in the most productive fields lead to the conclusion that under present conditions, or those of 1918, the ores are hardly as profitable with spelter at 9 cents a pound and silver at \$1.25 an ounce, as they were before the war with spelter at 5.5 cents a pound and silver at 60 cents an ounce.

CHAPTER XXV

GOLD STATISTICS, WARS AND PRICES

The statistics of gold production are easily obtained and on their face show remarkably little change during the last ten years. It is a common-place that the war period, 1914 to 1919, more especially the later part of it, was unfavorable to the business of gold mining. Other commodities and labor were in acute demand at prices far above those of former years, but gold remained nominally at the same price. Actually, of course, its price went down in proportion to the decline of its purchasing power. This finally resulted in a rather abrupt decline in production.

But the decline caused by war conditions does not fully explain the position of gold. It is reasonable to suppose that the output would have declined anyway in recent years, or at least would not have increased. South Africa accounts for half the world's yearly supply. The increase of production from 1900 onward has been largely the growth of the South African industry. In fact for the last fifteen years the African production has been the one source of supply that has raised the world output; without it there would have been a considerable falling off. Thus, in 1904 the world production was $347,377,000, of which Africa yielded $85,913,000, leaving for the rest of the world $261,464,000. In 1915, the year of greatest output on record, $468,725,000, Africa yielded $217,852,000, leaving only $250,612,000 for the rest of the world. In 1917, Africa produced $214,614,000; the rest of the world only $208,976,000. It is true that disturbances in some countries, notably Mexico and Russia, had something to do with this falling off, but this was not a controlling factor. The main thing is that no new supply of gold ore has been discovered; no new process for obtaining more gold from known sources.

Maximum Transvaal Gold Production in 1912.—The output has varied with the exploitation of districts already under operation. The Boer War, 1899–1902, retarded the growth of mining in the Transvaal, but as soon as recovery had been made from that, and the district had reached full and unhampered activity, the output of that country rapidly approached its maximum, and practically reached it in 1912. Since that year, with the exception of a spurt in 1915, there has been no indication of an increase of gold production. There does not seem to be any reason to anticipate a rapid decline in the near future; but to expect

the gold industry to hold its own for the next ten years is about as optimistic as one can reasonably be if reliance be placed on all factors turning out favorably.

Despite these facts, the price of gold has declined. Complaint of the high cost of living was general, even before the war. The amount of other commodities which a given amount of gold would buy has diminished steadily ever since 1894. The strange thing is that this diminution of purchasing value was accelerated during the war in the face of an apparently increased demand. These facts suggest various explanations:

1. It is not improbable that the money value of gold is governed, not by the current output, but by the total amount available in the world. Other metals, once put in use, are not available to any large extent for other purposes. Thus, iron put into railroads, buildings, machinery, tools, and like purposes, generally stays in those allocations until it is destroyed by rust or wear. Its manufacture is specialized for certain purposes. In general, it is cheaper to make new iron for a particular use from the ore than to remelt old iron, because such iron is not generally fit for the new purpose. Lead and zinc are used largely for paints, from which recovery of metal is impracticable. Copper is not so completely fixed, perhaps, nor quite so destructible, but by far the greater part of it is put at once into permanent structures from which it is seldom removed. Silver, even is exposed to considerable destruction by use in household ware, ornaments, corrosion and the wear of common small coins. But gold is not put to any large extent to any fixed allocation. It is merely locked up in treasure vaults to be used as standard for exchanging commodities. Some of it, of course, is used for ornaments and for coins, but even these are jealously guarded.

The Available Supply of Gold.—Almost all gold is capable of being remelted and put to another use. About the only means by which it is destroyed are the absorption of small amounts in chemicals, the wear of jewels and coins, and absolute loss. Thus the large output of the last twenty years has swelled the stock of available gold immensely more than similarly increased outputs of other commodities have increased the available stocks of those commodities. For instance, the available stock of manufactured or usable iron or copper or wheat ready for consumption is seldom more than a year's supply. If new supplies should be cut off, some part of these metals could be taken from the less imperative uses and put to more necessary ones; but there would be an immediate curtailment of industry, production, and comfort. The people would be headed straight for want and disaster. Of the iron and copper produced a hundred years ago, only an infinitesimal fraction is available for commercial purposes today; but, in the case of gold, a large percentage of that produced a hundred years ago is undoubtedly still subject to

exchange. In view of these considerations it becomes interesting to reflect upon the following statistics:

The Record of Gold Production.—The production of gold was stagnant and comparatively small until about 1850, when the great historic discoveries in Australia and California suddenly tapped the gold resources of two virgin continents. These supplies seemed abundant for all necessary purposes. In 1853, the output reached $155,500,000. This remained the record output for forty years, until 1893. Production stagnated or declined, going as low as $90,000,000 in 1874, and to $95,400,000 in 1883. In forty years, 1851 to 1890 inclusive, the total production was about $4,500,000,000. About 1890 a revival of gold mining took place, the production climbed to a new maximum of over $460,000,000 in 1912, and the total production of twenty-eight years, 1891 to 1918 inclusive, was $9,500,000,000.

There seems to be reason to believe that the world's stock of gold is at least three times as great in 1919 as it was in 1890. Various influences are in favor of the conservation of the metal. It is reasonable to believe that between 1850 and 1890 the proportion of the annual production lost through wear and wastage was much greater than it has been since then. Gold coins were in much more common use. The population among which the metal was exposed to absorption was proportionately greater. In 1890 the new gold per capita was only about 10 cents per year; in 1915 about 30 cents. Now, suppose that at all times each person wears out 5 cents' worth of gold a year. In 1890 such wastage would have been 50 per cent. of the total supply; in 1915 it would have been only 16⅔ per cent.

From these observations it may be perceived that though the annual production of gold is not increasing, but actually diminishing, the amount may still be sufficient to swell the available stock of gold even beyond the proportionate demand for it. It is not unlikely that between 1860 and 1890 the stock of gold did not increase in proportion as fast as the general business of the world, and its purchasing power steadily increased, but that since 1890 the stock has increased faster than the world's business, and its purchasing power has proportionately diminished. It is probable that about 1890 the supply of gold ran so low that the demand for it would account for the low prices for commodities of the early '90's. To illustrate this, consider some hypothetical figures.

Suppose that the available stock of gold in 1850, the accumulation of all former times, was $1,000,000,000, and that between 1850 and 1890, half of the gold produced was added to the stocks. The accumulation would be about $2,250,000,000 in the period, and the total supply in 1890 would be $3,250,000,000. Assume, further, that of the total gold produced since 1890, an amount equal to 80 per cent. has been added to the stock. The accumulation would be $7,600,000,000 for the period and the present total amount would be $10,850,000,000.

Relation of Gold Supply to Industrial Development.—If these figures are even approximately correct it becomes probable that the stock of gold in proportion to the production of the chief staples of commerce is much greater today than it was in 1890; that is, there is more gold in existence today to be exchanged for available iron, coal, copper, wheat or cotton than there was in 1890. In this connection it may be remembered that in the latter part of the nineteenth century the expansion of the world's commerce was proceeding at a rate that perhaps has not been equaled since then. It included the opening up of the interior of America, Australia, and Africa, the construction of nearly all existing railroads, the development of mechanical manufacturing, the factory system of employment, and the creation of most of the great industrial corporations. Since that time business and wealth have continued to expand, but more through the development of specialties and refinements, less, perhaps, through the discovery of new resources and processes, and very likely not at the same rate as in the earlier period.

2. Emphasis should probably be laid upon the tendency to conserve gold more and more for the purposes of exchange. Gold for many years has been handled almost exclusively by banks and the treasuries of the leading nations. Its use as common coin has proportionately diminished. Of late years, as a war measure, all the leading belligerents have suspended specie payments, so that the ordinary citizen has scarcely been able to obtain gold for any purpose. It seems possible that this should be regarded as an additional and special factor superimposed upon the tendencies outlined. It makes gold as a medium of exchange seem distant, even imaginary; it enables governments to make gold go further than ever as a basis of money, and makes the average man use "money" with less and less thought of obtaining the metal.

Gold More Plentiful Than Goods.—At any rate, whatever the relation of gold to prices, it is evident that, as a result of the recent war, gold, for the uses to which it is put, is relatively more abundant than are the principal staples of commerce. Apparently this is the result of every war to a sufficient degree to cause extensive borrowing by governments, the diversion of large numbers of men from productive occupations, the derangement and prostration of industry through interruption of supplies, and the laying waste of productive areas. If conditions were normal, considering the feverish demand for exchange, a strong demand for gold at the present time might be expected; but the feverish conditions are in themselves a proof of want, and the want of food, tools, and equipment is more insistent than the demand for gold.

A book should be written upon the effect of great wars upon prices and general economic conditions. I have inquired for such a publication, but have not heard of one. In the absence of an authoritative discussion, I am tempted to put down a few observations that I have been able to glean from various sources.

Industrial Status of Napoleonic Era.—At the time of the Napoleonic wars the modern industrial world was in its infancy. Only one country—Great Britain—had made any progress to speak of in the use either of mechanical power or intensive manufacture. The population of the leading countries of Europe was from one-quarter to three-quarters of what it is today. Production was generally by handicraft and not by the factory. Transportation of staples was only beginning. Commerce, therefore, beween distant points had been confined largely to rare and valuable fabrics and luxuries. Dependence upon the resources of other continents was not at all general but was confined amost entirely to the countries at the western fringe of Europe. During that war an almost complete monopoly of ocean traffic fell to Great Britain and to the comparatively feeble and loosely organized United States. Through this combination of circumstances Great Britain, although at that time producing little or no gold from her own territories, undoubtedly became the principal gold owner of the world and adopted the gold standard. It was a period of general enlightenment, of increased knowledge of distant countries, of progress in natural science, of bold intellectual speculation.

The Financial Panic of 1819.—The economic effects were chiefly the diversion of handicraftsmen into military pursuits, including the manufacture of military supplies, and a derangement of ocean commerce which, after all, deprived only a comparatively small number of people of their accustomed supplies. Furthermore, there was an increase of the public debt, which in the case of England, at least, dwarfed anything ever known before. These causes were sufficient to produce a general and prolonged rise in the price of many commodities of general commerce. The effects varied greatly from place to place, depending upon whether or not they were exposed to direct ravages. The wars themselves were confined to a period of twenty-five years, but the prices of some commodities continued high for forty years, or for fifteen years or more after the war. The economic readjustments at the close found expression in an acute financial panic in 1819, four years after Waterloo.

Effects of Nineteenth Century Wars.—In the middle of the nineteenth century, between 1855 and 1870, a number of comparatively localized wars disturbed the industrial world. Of these, by far the most important was the Civil War in America. The Crimean War of 1855 and 1856, the Italian War of 1859, the Austro-Prussian War of 1866, the Franco-Prussian War of 1870–71 were either short lived or affected regions of slight industrial importance. But the combined effects were a considerable increase of public debt, very large in France and the United States. During the Civil War there was an important stoppage of one of the world's chief staples—cotton.

Again, there was a prolonged rise in the price of commodities, which

culminated in 1864, but which persisted at least until 1880. It may be remarked, in passing, that the severe financial panic of 1873 had little effect on checking the high prices.

Just preceding this series of political disturbances occurred the unprecedented discoveres of gold in California and Australia, which not only increased the supply of that metal at an extraordinary rate, but stimulated exploration, colonization enterprise, and trade in all parts of the world. At no other period in the world's history, except, perhaps, at the time of the Spanish conquests of Mexico and Peru, was the supply of gold increased so rapidly or so generally distributed. The concurrence of this fact with a period of political disturbances and a succession of wars brings about a confusion of economic causes which it is probably very difficult to unravel; but there is certainly every reason to suppose that the increase of gold supply had a good deal to do with stimulating demand and raising prices.

After the Franco-Prussian War there supervened a period of general tranquility among the chief civilized and industrial nations that lasted, with slight interruptions, for about forty years. In the earlier part of this period there was a general payment or reduction of public debts and also the stagnation and decline of the output of gold, together with a great expansion of agricultural development. Prices steadily declined until about 1895. At this date the payment of public debts had ceased and the reverse tendency began. Just what caused this condition I have not inquired into critically, but it is not improbable that it was attributable to the renewal of international rivalries, the increase of of armaments, and the initiation of national enterprises. At the same time the production of gold had for several years increased rapidly.

The events of the mid-century find some parallel in more recent ones. Again a greatly increased gold production concurred with a period of general prosperity. Wealth and luxuries were produced in unexampled profusion and in new forms. The gas engine, the automobile, and, finally, the airplane were developed and added much to the convenience, activity, and information of millions. Industry was organized in immense units, producing the staples of commerce with much greater facility and in many times greater volume than had ever before been known. These activities centered in certain areas which became the industrial clearing houses of the world. Those areas became populated to such an extent that the people in them were and are absolutely dependent for their prosperity and even for their subsistence upon the constant interchange of staples on an immense scale.

Development of National Rivalries.—Great Britain was the first of the principal nations to feel conscious of such dependence upon trade, but with the rapid increase of population, manufacture, and commerce in Germany, that nation became thoroughly conscious of it also. On the

other side of the world, too, Japan found herself confronted with the same problem. Thus the principal industrial areas of the world were, by the measure of their indigenous resources, overpopulated. In Europe these areas were occupied by different nations, each imbued with jealousy of its neighbors and intensely unwilling to permit the continuance of its trade, and therefore of its life, to be in any measure at the mercy of its rivals. Thus overpopulation was certainly the underlying cause of formidable international rivalries, giving rise to innumerable schemes of expansion aggression, and defence; and determining the tone of thought by which such schemes were supported.

The series of wars prompted by these motives has already been long. It includes numerous minor conflicts incident to colonial aggressions

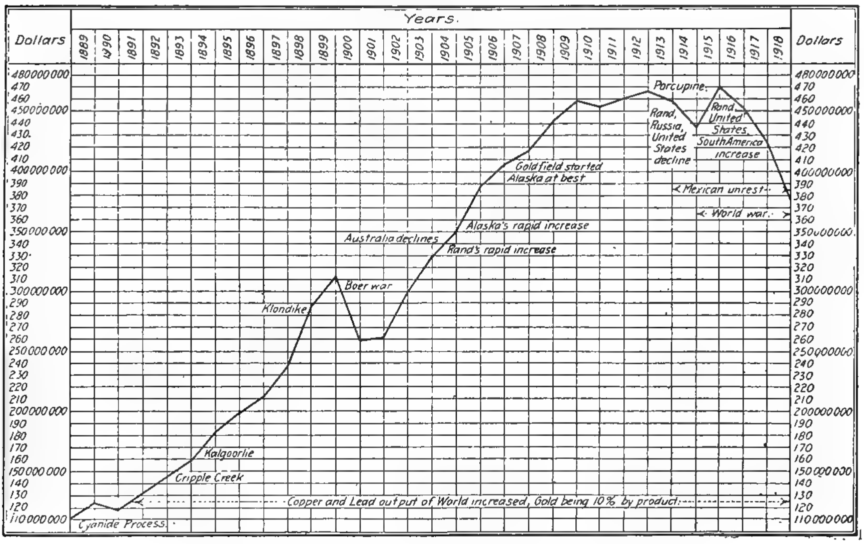

FIG. 10.—Gold production of world for 30 years.
(According to M. W. von Bernewitz.)

of the Europeans, though the collisions between great nations were avoided until the Russo-Japanese War of 1904–1905. But war in Europe was constantly brewing, and was with difficulty avoided on many occasions. Finally, a furious war, all the more violent because so long repressed, involved all the principal nations of the world.

The events of the Great War have accentuated rather than mitigated, in Europe at least, the force of the economic conditions outlined. Those who take pains to look the situation in the face must be impressed with the following facts: The total white population of the world is about 600,000,000. Of these, three quarters live in Europe. The total area occupied by white populations is about 20,000,000 square miles, a good part of which is in the circum-polar regions of America and Asia and an-

other portion in the deserts of Australia. Of this population, half at least, both in number and in area occupied, have been thrown into a state of political revolution and social and economic chaos, and are today suffering in varying degree from all the distress incident to such terrors, from starvation, exposure and danger. Out of the ruins of the empires of Russia, Germany, Austria, and Turkey a number of small nations have been created, or resurrected, without fixed organization, all jealous of their neighbors; some already at war with each other, and each nation far less self-sustaining than the larger units from which it was broken. When it is considered that revolutions, once started, are hard to stop and frequently go on from one stage to another for generations, it is hard to look upon the general situation of the white race with much assurance of a complete return to tranquility and prosperity.

These conditions do not affect the Anglo-Saxon world within its own territories as they affect every other white nation. The Anglo-Saxons are, as I have pointed out elsewhere, richer in resources, stronger in industry, and firmer in political organization than any other nation; and these facts have been demonstrated as much by the recent war as by anything that ever happened. But the solidity of the English-speaking countries is not the only factor in their relations with the world, unless they can shut out and ignore the rest of that world—and that is precisely what it is proposed not to do.

The economic consequences of such a cycle of events have been just such as one might expect from an attentive consideration of historical parallels. But in this case the tendencies that have been visible on former occasions have operated with multiplied intensity. Prices of staples have been forced to heights only the extreme peaks of which have been passed. It is hard to escape the conclusion that the main factor in these high prices is the tremendous national borrowings. The world has financed itself with promises. There has been a steady decline in the purchasing power of these promises.

To return to the general figures mentioned, there are 600,000,000 white people divided among various nations. These nations owe about $200,000,000,000. At a conservative average, each individual owes about $300 and each head of a family $1,500. The theory is that these sums must be paid, principal and interest, not out of product but out of profit—out of savings. It is only, of course, when these debts are owed by one nation to another that these sums mean an actual transfer of goods. The debts of a nation to its own citizens can be paid only through taxes from those citizens, so that, although the process may affect individuals variously, in a national sense it is merely a transfer from one pocket to another. The overwhelming preponderance of public debts must be of this nature. But is it not true that the necessity of giving these pocket-to-pocket transfers the semblance of real money is the potent cause of marking up prices? How can it be avoided?

The actual wealth is not money but goods. A nation can produce only a given amount. To repay itself vast sums of money through taxes for interest and principal can be accomplished only through adding to the value of the goods the amount of the taxes. As this addition to value is not expressed in goods, but in money, it follows that the sum total of goods must be expressed in a larger amount of money, i.e., in inflated or imaginary value, a decreased purchasing power of the dollar, or higher prices—all these expressions meaning the same thing.

Hennen Jennings has pointed out that the only effective check upon the progressive depreciation of the unit of value through these causes is free payment in gold. An ounce of gold is divided into something over twenty dollars. It costs as much effort and as much goods to produce the gold ounce or the gold dollar as it ever did. Therefore, so long as the dollar actually represents a given amount of gold it will always represent a given amount of effort. If a given amount of effort made highly efficient by improved organization and appliances can be made to produce a greater amount of goods, it is likely, also, to produce in a general way a proportionately greater amount of gold. The only influences that would permanently alter this relationship would be fundamental causes, such as the discovery or exhaustion of great sources of gold by which the metal might become relatively easier or more difficult to obtain. When it is obtained only at greater effort than is necessary in the acquisition of other commodities, or through consumption in process of its production of greater quantities of other commodities, then, if secured at all, it must be acquired through the use of greater quantities of those commodities, and it will be manifestly equal in value to a greater quantity of them—will buy more of them. Prices will then be low.

The contrary process is equally imaginable and to specify it would only be repetition.

Thus gold, if freely used, is probably as dependable and fair a medium of exchange as could be devised. It may be remarked further that its equilibrium is maintained in the long run through natural causes which, of course, do not operate instantly, but which do tend to confine the oscillations of value between comparatively narrow limits. If gold is produced in quantity greater than the demand for it, people will not pay so much for it in commodities. This is equivalent to a rise in cost which will force some producers out of business. On the other hand, if the stock of gold runs short, prices will be low, and the inducement to mine more of it will return.

It is pertinent to remark that the influence of prices upon gold production is bound to be felt in the long run, regardless of the cause of the change of prices. It makes no difference in the ultimate effect on the gold industry whether high prices are brought about by the existence of an abnormally large stock of gold, or by the shortage of commodities

brought about by decreased production of them for any reason—wars, disasters, disorder, or famine; the tendency will always be to curtail the production. Such influences will bring about considerable swings in the popularity of the industry. The reasons which operate to make gold mining unprofitable will discourage or diminish the search for gold. Plants will go out of business, and a considerable period will elapse before the counter-swing will have much effect.

The gist of these considerations is that in the cycles of high and low prices it is possible to discern the operation of common economic laws An outburst of national borrowing is in itself either a diversion of labor from its usual channels of production or an evidence of distress brought about by the shortage of production from some other cause. It will either produce high prices or be produced by them. On the other hand, the widespread liquidation of borrowings can be accomplished only during the periods of tranquility when labor is employed in full measure for the production of private wants, when there is freedom from calamity. A war, therefore, unless it is local and insignificant, is sure to raise prices. The more general and violent the war, the wider its effect in raising prices. Moreover, the effect of war is not confined to the period of organized military effort, but will persist as long as the exhaustion of resources, the impeding of traffic, and political and social disorders prevent the resumption of peaceful industry in an efficient manner.

The inducement to produce gold will naturally follow upon these influences. Its production will be curtailed during the whole of the period of high prices and high costs, and will not be resumed with full impetus until it has been encouraged for some years by low prices, which means a glut of the chief staples.

It certainly is to be expected, and feared, that the present situation of the world indicates a long-continued periof of high prices for reasons which may easily be summarized in the order of their importance:

1. Every new or revolutionary government is necessarily unstable. Every nation between the Rhine and Vladivostok and from the Arctic Ocean to the Mediterranean and the Himalayas is the seat of potential, even prospective, revolution. The population of this tract is as follows:

Russian Empire	170,000,000
German Empire (including Poland)	65,000,000
Austrian Empire	53,000,000
Balkan States and Turkey	40,000,000
Total	328,000,000

Every nation in this group is confronted with a long list of burdensome tasks which must be accomplished despite the probability, according to historical precedent, of having its projects deranged by internal disorder. It must establish, or re-establish, public and private credit. It must

establish new, or re-establish old, lines of trade and traffic. It must restore or replenish its stock of staples and raw materials, and it must make provision for the payment of foreign debts. How easy it is for national and racial jealousies, actual or latent disorders, to prevent all this, not only locally but throughout the whole area!

2. The white populations unaffected by revolution are as follows:

British Empire	60,000,000
United States	100,000,000
France	40,000,000
Italy	35,000,000
Spain, Portugal, Netherlands, Scandinavia	45,000,000
South America—Brazil, Argentina, Chile	20,000,000
Total	300,000,000

These countries are in control of the resources of the greater part of the world, but by a very unequal division. Of the chief resources, the Anglo-Saxons control the preponderance. On the whole, however, there is nothing to prevent this group from resuming, or even increasing, its former prosperity. By returning to peaceful industry, the major portion may soon replenish its warehouses. The chief difficulties are the curtailment of national expenditure and the liquidation of foreign debts. To whatever extent these operations are dependent upon the prompt payment of obligations and a resumption of good feeling by the great disturbed populations of central and eastern Europe, northern Asia (and it may be added, perhaps, of China and Japan), their success can hardly be regarded as present as other than doubtful.

Even if it is reasonable to believe that the recent cycle of political, social and economic disturbance has passed its acute stage, it still remains certain that these distractions have operated upon a scale and with an intensity scarcely ever known before; and the time required for recovery should logically be at least as long as at any former period. On this reasoning one might expect that the present cycle of high prices will not have fully subsided until about 1940, at the best.

CHAPTER XXVI

OCCURRENCE AND PRODUCTION OF GOLD

VALUE OF GOLD AND TRANSPORTATION—ECONOMIC PHASES OF GOLD MINING—PLACERS—AMALGAMATION—CYANIDE AND OTHER RECENT PROCESSES—ECONOMIC DISTINCTIONS OF GOLD ORES—QUARTZ-PYRITE LODES—REASONS FOR VARIATIONS IN COSTS—TELLURIDE ORES AND DISTRICTS—TABLES OF GOLD PRODUCTION—PRODUCTION OF VARIOUS DISTRICTS—COST OF PRODUCING GOLD PER OUNCE—PROFITS OF GOLD MINING COMPARED WITH THOSE OF OTHER METAL MINES.

Within recent years gold has become more than ever before the precious metal *par excellence.* Its production has not only increased enormously in amount, but also greatly by comparison with its historic rival, silver. A general description of its qualities has no place here, but it will be interesting to review the more salient features of its occurrence bearing on its production and cost.

A ton of pure gold is worth $602,836. This high value renders the metal, once secured, utterly independent of transportation costs, for it is evident that it can be carried from the remotest corner of the globe for a minute fraction of its worth.

Another equally important fact is that gold occurs to an exceedingly large extent in such form that its extraction from ores is one of the simplest of metallurgical problems, so that it can nearly always be obtained by plants erected on the spot. The cost of such plants per ton treated is moderate. The avidity with which gold has been sought has resulted in the exhaustion of the mines in the older civilized countries so that at present the output comes from new or barbarous countries where, for the most part, the climate is bad, labor costly, and transportation crudely developed. In the case of gold mines, therefore, the question of transportation has little or nothing to do with moving products *from* the mines, but much to do with moving plants and supplies *to* the mines.

The history of gold mining exhibits three economic phases with reference to mechanical developments: These may be divided chronologically into, (1) The placer period. (2) The amalgamation period. (3) The cyanide and smelting period.

1. From the earliest times down to the present gold has been very largely obtained in a metallic state from the débris of erosion, *i.e.*, from stream gravels. Owing to its great weight gold resists transportation by water and lags behind while the lighter minerals are carried off to the sea. In this way each stream in a gold-producing country is a natural

concentrating mill and often retains the metal, or a portion of it, that was once scattered through enormous masses of rock. How great this concentration may be is perhaps not fully realized even by mining men. A stream bed 100 miles long and a quarter of a mile wide and a few feet deep may have gathered gold derived from thousands of cubic miles of eroded rock. The gravel that now contains the gold may equal only a millionth part of the mass that once contained it. Undoubtedly in every such case a very large portion of the original gold has also been removed, but if even one per cent. has remained, the gravel may be ten thousand times as rich in gold as the rock from which the gravel was derived. It is evident, therefore, that streams may contain highly profitable deposits in regions where the gold was originally scattered through a multitude of insignificant veins, all worthless in themselves. The presence of placer gold in payable amounts does not indicate that payable gold will be found *in situ.* Many cases might be cited of important placer mines in regions where there has never been a good mine of any other kind. To be sure quartz mines have been found in Alaska, California, Australasia, and many other regions along with placer deposits. On the other hand, in early times placer gold was obtained in Spain, France, the British Isles, Italy, in fact all over Europe where scarcely a payable quartz mine has been known. It is almost certain that the older civilized countries, Northern Africa, Western Asia, China, India, and Japan, also produced a full quota of this metal from sources now long forgotten.

It is highly probable that by far the greater part of the gold possessed by mankind, even now, came from placer deposits. Nearly all gold was obtained in this way until well into the nineteenth century by the process of mere washing, unaided by amalgamation or any metallurgical process.

2. The properties of quicksilver have been known from very early times, and undoubtedly since about the time of Columbus this metal has been used to a large extent to collect gold out of its gangue in both placer and quartz-mining operations. But it was not until the almost simultaneous discovery of gold in California and Australia at the middle of the nineteenth century that amalgamation came to be the essential process in the recovery of gold. Before the working of extensive quartz mines in those countries amalgamation was used as a useful adjunct in cleaning up the concentrates from gravel washing, but for that purpose it was not vital. But from 1850 to 1890 this process was the only one successfully used by English-speaking people, who have since 1850 produced most of the world's gold, to extract the metal from rocks in place.

The method was found to apply only to ores in which the gold lay in rather loose metallic particles in the rock. It is essential for amal-

gamation that the gold when it adheres to the quicksilver will be free from adherence to other minerals. In course of time more and more gold ores were found where this was not the case. It was found that most gold veins produced amalgamating ores in the oxidized zones near the surface, but that only selected ones would yield their values in this way after the sulphide zone was reached. Where an extraction of 70 to 90 per cent. was easy in the oxidized zone, the extraction would drop to 60 or 50 per cent. in the sulphides. At the same time the actual assay value of the ore would show some diminution. These two causes were sufficient to render many a mine unpayable. Although some mines continue to be perfectly amenable to amalgamation to great depths, there were found so very many where this was not so that gold mining began to decline, especially during the eighties. This decline was due to the limitations of the amalgamation process.

3. The ingenuity of metallurgists discovered about 1890 remedies in leaching processes that would extract gold independently or could be used as supplements to amalgamation. These were based on the solubility of gold by chlorine gas and by various cyanides. In one form or another these chlorination and cyanide processes were found to apply to most gold ores. This happened at a time when the world was hungry for gold. Great districts were found like the Witwatersrand where by amalgamation the ores would pay only in selected cases, but with the additional values saved by the new process would pay handsomely. There was a great revival of the gold industry, which has grown rapidly ever since.

It would be hardly proper to infer that the whole increase of gold production is due to the cyanide and other leaching processes. The old sources of gold supply have not disappeared. Placer mining in Alaska has developed a respectable output. Placer mining in general has been aided by improvements in mechanical appliances, of which by far the most important is the dredge. An increasing amount of gold is also obtained by the smelters as a by-product of lead and copper ores. But it is entirely proper to state that since 1890 the improvements in gold-mining practice have been such as to warrant calling this period a new era in the industry.

Economic Distribution of Gold Ores.—On economic grounds we cannot follow with any satisfaction any division according to the processes used. Various processes are often used simultaneously, one supplementing the other. I plan to discuss gold mines under the two general groupings of placer deposits and vein deposits. Of placer deposits nothing more need be said here.

Gold Veins or Gold Deposits in Situ.—By far the most important source of gold known to-day may be called, for want of a better name, the quartz-pyrite lode. In these deposits quartz is always the main

constituent. With the quartz there is always a certain proportion of iron pyrite, usually less than 5 per cent. of the mass, but varying from $\frac{1}{4}$ per cent. to 50 per cent. Sulphides of lead, copper, and zinc may also be present, but usually in very subsidiary quantities. The lodes occur in every conceivable attitude and manner. They are of every geological age from the oldest to the youngest. The ores may fill open crevices or fissures caused by shrinkng or faulting in the rocks, they may be replacements of other rocks, they may simply fill up the interstices of pebbly beds or conglomerate. In all cases it is highly probable that quartz-pyrite ores were deposited by hot waters of deep-seated origin. In many cases there is reason to believe they came from "magmatic" waters, waters once included in molten rock masses, that escaped when the pressure was released. In almost all cases there is some reason to believe that these deposits have a connection, not always explained, with igneous rocks.

These ores occur in large volume. In many cases millions of tons are in sight. The Treadwell group in Alaska has mined 14,000,000 tons and reports 7,000,000 in sight, averaging $2.40 per ton. The Witwatersrand mines have treated 114,000,000 tons and expect to mine some 500,000,000 tons more, averaging $7 or $8 a ton. Four mines in the Mysore group in India have mined 7,300,000 tons, averaging $18.40 per ton, and have in sight 1,400,000 tons averaging $20. Three mines at El Oro, Mexico, have produced 2,450,000 tons averaging $16 per ton, and have in sight some 900,000 tons averaging $11. The Witwatersrand mines are now treating 20,000,000 tons a year. These figures show that this class of gold mines constitute a great industry carried on under conditions of stability not inferior to those of other kinds of mines. It will be shown later that they are as profitable as any.

In these ores the gold is said to be almost entirely in a metallic state, scattered through the gangue in particles of varying size. Sometimes, for instance, at the North Star mine, in California, 90 per cent. of the gold can be recovered by amalgamation. In other cases, as at El Oro, Mexico, and Goldfield, Nevada, only 10 per cent. or even less will amalgamate. The difference is due not to the state of the metal itself but to its degree of subdivision. In some cases the gold is in such minute particles that, even with the finest grinding, it still remains partly imbedded in particles of gangue. The gold is much more apt to be imbedded in the sulphides than in the quartz, hence it often happens that the alteration of the sulphides by artificial oxidation or roasting sets free a good deal of it. But in this class of gold ores roasting is practically never necessary for a good extraction by leaching processes. It is here that the cyanide process has its great field.

Cost of Mining and Milling Quartz-Pyrite Ores.—In both mining and milling the cost is most affected by two dominant factors:

(*a*) The richness of the ore.

(*b*) The size of the deposits.

The richness of the ore affects both departments of the operation through its effect on the elaboration of processes. In the case of low-grade ores the process *must* be cheap, therefore cheapness is secured if necessary by sacrificing part of the ore in both mining and milling. In the case of the Treadwell an ore is mined that assays $2.70 per ton. It is mined, let us say, for $1.15 and milled for $0.35 with an extraction of 75 per cent. by mining and 90 per cent. by milling, making a total saving of 67½ per cent. The profit per ton actually milled is $0.93. Now to save more of the ore, to save 90 per cent., would involve the institution of another method of mining which would certainly be more expensive. Such a method would almost certainly cost over $2 a ton and would therefore wipe out the profits altogether. In the case of milling the only improvement that should be made would be by cyaniding the tailings which only run 27 cents a ton. Under the most favorable conditions this would not pay.

But if we consider the Mysore mines in the same light we get utterly different results. These ores assay $20 a ton. To sacrifice 25 per cent. in mining such ores would be to leave $5 per ton in the ground. To spend $3 or $4 a ton more to secure this would be entirely proper, although such a figure is twice the whole cost of the Treadwell process. In milling a loss of 10 per cent. means $2 a ton, and likewise, to spend say $1 per ton more to save half the loss would be good business. In a word, the cost of $10 a ton for the Mysore ores may be just as sound business as the cost of $1.50 at the Treadwell; and this for no other reason than the greater value of the ore.

Size of Orebodies.—With orebodies of the same size we may vary the cost within wide limits at will, as just shown; but human will has no effect on the size of orebodies: we must take them as they are. The size and attitude of the masses to be attacked hedge the cost of mining with limitations even more arbitrary than those imposed by the grade. A uniform bed 6 ft. thick of ore of this character can be handled at a total cost, on average conditions throughout the world, of $3 a ton. A bed 4 ft. thick will cost somewhat more, say $3.50 a ton. Below 4 ft. the cost will rise almost in inverse ratio to the thickness, so that a seam 1 ft. thick will cost $14 a ton, and so on. Now it often happens that most important gold ores do occur in such narrow streaks. In the Witwatersrand the values are usually confined to streaks from 4 inches to 16 inches thick, worth from $20 to $100 a ton. Under the cost conditions ruling in that district a 4-inch seam would cost approximately $60 a ton. This would leave a profit, supposing the ore to assay $100 a ton and that the extraction is 95 per cent., of $35 a ton, equal to 35 per cent. of the assay value. But mining is not conducted that way. Such a

seam is mined in a stope at least 4 ft. wide; the ore seam is mixed with an enormous amount of waste, ten or eleven times as much waste as ore. The ore going to the mill will run only $8 a ton and the cost is $5; but the proportion of profit is about the same. Wherever it is possible to mine such seams by themselves, it should be done; but on account of the friable nature of the streaks, in many cases there is so much danger of loss in breaking the ore that it is considered safer to mill most of the stuff broken regardless of its value.

But these considerations do not affect the real cost of mining. In the case cited above the real orebody is only 4 in. thick and the cost is $60 a ton. That the value is diluted and the cost lower is only a matter of convenience. That such orebodies would be worthless if the ore streaks yielded even such apparently attractive assays as $40, $20, to say nothing of $5, a ton is too obvious to argue about. Strange as it may seem, great quantities of money are lost by attempting just such impossibilities.

Other Causes of Variation—Quartz-pyrite ores are metallurgically simple, and outside of the two great factors mentioned above there is nothing to make very great differences in cost. So far as underground operations go the variations are so nearly wholly due to those factors that others may be neglected. In milling, the metallurgical problem, on average ores of say $10 a ton, will cause variations between a minimum of about 75 cents and a maximum of about $2.

The process is in principle uniform throughout the world. It consists of one or all of the following steps:

1. Amalgamation after crushing in stamp batteries.
2. Concentration of refractory sulphides.
3. Leaching of tailings (or, in some cases, the original ore) by cyanide or other solutions.

Where concentration is undertaken, it is only in order to apply some special process to a small fraction of the ore. Such a process may be instituted at the mine, or the concentrates may be shipped to custom plants; but in any case the cost as applied to the crude ore is never very high, because for each ton of concentrates there will be from 10 to 100 tons of crude.

So many examples of the cost of these processes in actual practice will be found in the following chapters, that I shall not discuss them further here.

Other Gold Ores.—In the type discussed above the gold is in the ore free, or native, *i.e.*, it is mixed mechanically, not chemically, with the gangue. In Cripple Creek, Colorado; Kalgoorli, West Australia, and in a number of other less important districts, the gold occurs to a large extent as a true ore, namely as tellurides. Here the gold is involved in a chemical combination with tellurium and to a less extent with other

elements. Here amalgamation, except to a limited extent in the oxidized zone, is utterly ineffective. Dependence must be had on smelting or on leaching processes of a type inherently more expensive than those applied to quartz-pyrite ores. The reason for this is that in the raw state, the gold, or a large part of it, will not desert its companion minerals to unite with those offered by the leaching solutions. To get around this difficulty it is necessary to break up the tellurides by roasting before attempting to leach. To do this costs $1.50 a ton. This cost is not wholly for the roasting itself, but is due partly to the fact that ordinary wet crushing by stamps is not desirable when roasting is to be done. It is necessary to resort to the much more costly process of dry crushing.

Production of Gold in the United States, by States (*a*)

States	1915		1916		1917		1918	
	Fine Ounces	Value (*b*)	Fine Ounces	Value (*b*)	Fine Ounces	Value (*b*)	Fine Ounces	Value (*b*)
Alabama	247	$5,100	358	$7,400	106	$2,200	30	$700
Alaska	808,346	16,710,000	780,037	16,124,800	709,729	14,671,400	440,622	9,108,500
Arizona	220,392	4,555,900	197,989	4,092,800	250,613	5,180,600	278,647	5,760,200
California	1,090,731	22,547,400	1,063,302	21,980,400	1,012,461	20,920,400	842,389	17,207,000
Colorado	1,089,928	22,530,800	928,075	19,185,000	772,766	15,974,500	621,791	12,853,500
Georgia	1,684	34,800	987	20,400	314	6,500	169	3,500
Idaho	56,628	1,170,600	51,195	1,058,300	36,511	754,800	30,764	636,000
Missouri	....	....	....	....	15	300	10	200
Montana	240,825	4,978,300	209,386	4,328,400	177,690	3,673,200	153,375	3,170,600
Nevada	574,874	11,883,700	438,505	9,064,700	335,361	6,932,500	322,276	6,662,000
New Mexico	70,632	1,460,100	65,306	1,350,000	52,505	1,085,400	30,871	638,200
North Carolina	8,258	170,700	1,113	23,000	524	10,800	38	800
Oregon	90,321	1,867,100	91,985	1,901,500	81,624	1,687,300	60,951	1,260,000
South Carolina	174	3,600	15	300	82	1,700	....	....
South Dakota	358,145	7,403,500	361,444	7,471,700	356,662	7,372,900	328,305	6,786,700
Tennessee	329	6,800	276	5,700	267	5,500	263	5,400
Texas	87	1,800	24	500	5	100	5	100
Utah	189,045	3,907,900	186,670	3,850,000	170,353	3,522,100	152,018	3,142,500
Vermont	....	....	14	300	5	100	47	800
Virginia	24	500	24	500	63	1,300	20	400
Washington	22,330	461,600	28,087	580,600	23,617	488,200	16,556	342,300
Wyoming	672	13,900	977	20,200	179	3,700	18	400
Total	4,825,311	$99,748,000	4,405,778	$91,075,500	3,981,482	$82,304,500	3,269,171	$67,579,800
Porto Rico	34	700	29	600	5	100	....	....
Philippine Islands	63,898	1,320,900	73,249	1,514,200	69,953	1,446,100	44,202	913,700
Total	4,887,604	$101,035,700	4,479,056	$92,590,300	4,051,440	$83,750,700	3,313,373	$68,493,500

(*a*) The statistics in this table are reported by the Director of the Mint, those for 1918 being the preliminary figures. (*b*) At $20.67 per oz.

After roasting the processes usually proceed, so far as cost goes, about as in the case of quartz-pyrite ores of pretty high grade; for these tellurides ores are, on account of the high working cost, invariably of fairly high grade. They are often concentrated a good deal by hand sorting, so that when I speak of high grade I mean when they get to the mill or smelter. Referring to the rock actually broken in the stopes, the minimum grade of this type of ore that can be profitably worked is, under present conditions, about $8 a ton.

Cost of Producing Gold per Ounce.—It is to be remembered that fine gold is worth $20.67 per ounce. In order to gain some idea of the proportion of profit in gold mining as compared with other metals we may conveniently take the cost per ounce as an index. It is a current statement that gold costs more than it is worth. If one were to charge up against it the fruitless explorations and unprofitable enterprises of which it is the object it is impossible to conjecture how near true this statement might prove to be. Very likely those responsible for the statement and who believe it have never gone beyond the point of making a guess. In my judgment the statement is not any more true with reference to gold than with any other metal. Just as the selling price of copper is determined in the main by the costs obtained by the successful enterprises which are responsible for the major portion of the output, so the value of gold is established by the correspondingly successful properties and districts which yield the greater part of it.

In the Transvaal the proportion of total yield of gold that has been paid in dividends is almost exactly 25 per cent. The cost of gold, therefore, in this district which is yielding one-third of the world's output has been to date three-quarters of $20.67, or about $15.50 an ounce. This proportion is holding good at present, the record for the year 1918 showing dividends equal to 24 per cent. of the gross value produced, indicating a cost per ounce of about $15.70.

We might compare the record of the Robinson, at present the world's most profitable gold mine, against the Calumet & Hecla, the world's most profitable copper mine. The comparison is approximately as follows:

The Calumet & Hecla: gross value of yield about $312,000,000; dividends $108,500,000, which is 35 per cent.

The Robinson mine: gross value of yield $60,000,000; dividends $32,000,000, equal to 54 per cent.

In Cripple Creek, Colorado, I estimate the cost of gold to have averaged about $17 per oz. or 82 per cent. of its value, while the principal mine—the Portland—has secured gold at a cost of $14.50 per oz. or 70 per cent. of its value.

In Kalgoorlie, West Australia, I have no figures for the district at large, but seven or eight of the leading mines have paid dividends equal to approximately 40 per cent. of the yield in gold, so that the cost per ounce is only $12.40. These mines have furnished so large a proportion of the total yield of that district that it seems safe to conclude that the cost of the entire yield has not exceeded $15 per oz.

In the Kolar district of India, the four leading mines responsible for nearly all the output paid dividends equal to 44 per cent. of the gross value. Hence we conclude that the cost of gold has not exceeded $12 for those mines, and probably not over $14 for the entire district.

Gold and Silver Production of the World, 1493–1850
According to Dr. Adolph Soetbeer

Period	Estimated production in kilograms		Ratio of silver to gold, weight	Ratio of gold to silver, value	Period	Estimated production in kilograms		Ratio of silver to gold, weight	Ratio of gold to silver, value
	Gold	Silver				Gold	Silver		
1493–1520	162,400	1,316,000	8.1	10.75	1701–1720	256,400	7,112,000	27.7	15.21
1521–1544	171,840	2,164,800	12.6	11.25	1721–1740	381,600	8,624,000	22.6.	15.08
1545–1560	136,160	4,985,600	36.6	11.30	1740–1760	492,200	10,662,900	21.7	14.75
1561–1580	136,800	5,990,000	43.8	11.50	1761–1780	414,100	13,054,800	31.5	14.73
1581–1600	147,600	8,378,000	56.8	11.80	1781–1800	355,800	17,581,200	49.4	15.09
1601–1620	170,400	8,458,000	49.6	12.25	1801–1810	177,780	8,941,500	50.3	15.61
1621–1640	166,000	7,872,000	47.4	14.00	1811–1820	114,450	5,407,700	47.2	15.51
1641–1660	175,400	7,326,000	41.8	14.50	1821–1830	142,160	4,605,600	32.4	15.80
1661–1680	185,200	6,740,000	36.4	15.00	1831–1840	202,890	5,964,500	29.4	15.75
1681–1700	215,300	6,838,000	31.8	14.97	1841–1850	547,590	7,804,150	14.3	15.83

Gold Production of the World, 1851–1918

Year	Value	Year	Value	Year	Value	Year	Value
1851.....	$67,600,000	1871....	$107,000,000	1891....	$130,650,000	1911....	$464,346,495
1852.....	132,800,000	1872....	99,600,000	1892....	146,292,600	1912....	474,322,664
1853.....	155,500,000	1873....	96,200,000	1893....	158,437,551	1913....	462,669,558
1854.....	127,500,000	1874....	90,800,000	1894....	182,509,283	1914....	439,078,260
1855.....	135,100,000	1875....	97,500,000	1895....	198,995,741	1915....	470,466,200
1856.....	147,600,000	1876....	103,700,000	1896....	211,242,081	1916....	454,176,500
1857.....	133,300,000	1877....	114,000,000	1897....	237,833,984	1917....	423,590,200
1858.....	124,700,000	1878....	119,000,000	1898....	287,327,833	1918....	373,000,000
1859.....	124,900,000	1879....	109,000,000	1899....	311,505,947	....	....
1860.....	119,300,000	1880....	106,600,000	1900....	258,829,703	....	....
1861.....	113,800,000	1881....	103,102,000	1901....	260,877,429	....	....
1862.....	107,800,000	1882....	102,000,000	1902....	298,812,493	....	....
1863.....	107,000,000	1883....	95,400,000	1903....	329,475,401	....	....
1864.....	113,000,000	1884....	101,700,000	1904....	349,088,293	....	....
1865.....	120,200,000	1885....	108,400,000	1905....	378,411,754	....	....
1866.....	121,000,000	1886....	106,000,000	1906....	405,551,022	....	....
1867.....	104,000,000	1887....	105,775,000	1907....	416,101,396	....	....
1868.....	109,700,000	1888....	110,197,000	1908....	443,355,856	....	....
1869.....	106,200,000	1889....	123,489,000	1909....	458,424,058	....	....
1870.....	100,900,000	1890....	118,848,700	1910....	453,766,523	....	....

Gold Production of the World, by Countries[1]

	1916	1917	1918
Transvaal	$192,182,900	$186,503,400	$173,479,000
Rhodesia	10,232,200	17,245,000	12,862,000
West Africa	7,860,100	7,445,600	6,467,000
Kongo, Madagascar, etc	3,673,700	3,420,000	3,200,000
Total Africa	$222,948,900	$214,614,000	$196,008,900
United States	$92,590,300	$83,750,700	$68,493,500
Mexico	7,690,700	9,000,000	10,000,000
Canada	19,235,000	15,200,000	14,687,000
Central America	3,517,600	3,122,000	3,000,000
Total North America	$123,033,600	$111,072,700	$96,180,500

[1] Figures for 1916 and 1917 from Mint Report, 1918 estimated.

Russia, including Siberia	$22,500,000	$18,000,000	$10,000,000
France	1,000,000	700,000	500,000
Other Europe	1,019,900	1,017,000	500,000
Total Europe	$24,519,900	$19,717,000	$11,000,000
British India	$11,206,500	$10,756,800	$10,029,000
British and Dutch E. Indies	3,000,000	2,818,000	2,500,000
Japan and Chosen	9,308,000	9,006,200	8,500,000
China and others	4,495,400	5,035,400	4,500,000
Total Asia, not including Siberia	$28,009,900	$27,606,400	$25,529,000
South America	$15,188,400	$14,634,600	$14,000,000
Australasia	40,475,800	35,945,500	29,800,000
Total for world	$454,176,500	$423,590,200	$372,518,400

At El Oro, Mexico, the record of the three leading mines shows profits of 40 per cent., indicating cost of gold of only $12 per oz. It is not at all probable that the fruitless prospecting in that district would bring the total cost up to more than $14.

While it is not probable that such favorable showings for gold-mining districts can be extended to cover the whole list of districts, it is evident that the successful gold mines are fully as profitable as successful copper mines. The value of gold produced in the world is almost twice the value of the copper production, so that I feel warranted in saying that the current belief that copper mining is the most profitable form of mining enterprise, and that gold mining is one of the least profitable, is far from justified. It is to be remarked, however, that in the United States copper is a more important product than gold and it is in the hands of a smaller number of much larger concerns, which have paid larger dividends than any individual gold mine. In the world at large the reverse is true. This was in 1908.

In 1918, owing partly to the change of prices, partly to the change in relative production, the value of copper produced was nearly twice that of the gold.

If one were looking for an example of the comparative instability of precious-metal mines, and the dependence of the world for its supplies upon a constant search for deposits in all parts of the world, one would need go no further than to note the changes in the list of representative gold mines, selected particularly because they seemed the most substantial of their type. In the short interval of ten years the Alaska-Treadwell group has practically gone out of existence. So has the Camp Bird, El Oro and Esperanza, the Robinson, the principal Kalgurli mines, and the Goldfield Consolidated. Of those still running, in some cases with a marked decrease of prosperity, one may name only the Homestake, the

Liberty Bell, the Kolar mines, and the Portland. Thus the operations that have practically vanished are about ten out of seventeen, about 60 per cent.

Decline in Producing Districts and Little Progress in Metallurgical Methods.—This is not all. In the interval two great projects in Alaska for mining the low-grade gold ores of the Juneau district have been initiated, supported enthusiastically, and have proved themselves dismal failures. Districts have not been so roughly treated as individual mines, but even districts have so nearly lost their importance that it is scarcely an exaggeration to say they have vanished. To specify such vanishing districts one may name Douglas Island, Juneau, Ouray, Goldfield, El Oro and Kalgurli. In Cripple Creek and Kolar the output is steadily on the decline. Only at the Homestake and the Transvaal has there been an increase. The latter district produces half the gold of the world, but substantially from a new group of operations, which, however, merely represent a migration, enforced, of course, to lower levels and outlying tracts.

So far as I can learn, not a single radical or even important change in the processes of gold mining has taken root during the last ten years. The appliances are the same to all intents and purposes, although there has been a considerable substitution of ball mills for stamps, some improvements in drilling machines, and some changes in cyanide practice. But the ground work is the same, and results are about the same. The grand feature of the history of the business has been the progress of an economic cycle unfavorable to gold mining.

CHAPTER XXVII

QUARTZ-PYRITE GOLD MINES

Treadwell group in Alaska—Exhibit of conditions and costs—Homestake—San Juan region in Colorado—Camp Bird—Liberty Bell—El Oro district in Mexico—Esperanza and El Oro mines—Kolar district in Mysore, India—Details of cost factors—Records of the mines—A question of bookkeeping—Witwatersrand—Average results—The Robinson mine—Generalizations on the price of labor and costs.

Included in the class of quartz-pyrite mines are all of the properties of the Witwatersrand in the Transvaal, in fact all the gold mines of South Africa, nearly all the mines in eastern Australia, those of the Kolar district in India, of El Oro in Mexico, of California, Nevada, and Douglas Island, Alaska. In general, these ores are a light-colored or whitish quartz containing from 0.25 to 10 per cent. of iron pyrite and other sulphides in varying but usually subsidiary amounts. The quartz and pyrite may fill open fissures, or they may be replacements of country rock, or the cementing material of beds of conglomerate. Deposits of this kind have proved to be extensive, often persistent to great depths, and are worked on a grand scale.

Treadwell Group.—The group of mines on Douglas Island, Alaska, known as the Treadwell, Mexican, and Ready Bullion, furnish ore for 780 stamps at the rate of 1,200,000 tons a year. This work with good reason stands at the head of the list of quartz-pyrite operations, furnishing an example of the simplest metallurgical problem, the lowest costs, and, I believe, the best management to be found in this class of mining. The external and internal factors which affect the results obtained are of great interest to the student of mine economics.

Robert Kinzie, later superintendent of all the mines, published in *Trans.*, A. I. M. E., Vol. XXXIV, a detailed account of these properties up to 1902; in addition to this we have the full and excellent reports issued by the companies. On the whole the information available is definite and satisfactory.

Along a great porphyry dike which cuts the black slate of Douglas Island, there are three or four large lenses or ore shoots where the dike has been profoundly altered and silicified by the action of magmatic waters. The largest and most northerly of these is the Treadwell orebody, which was 400 ft. wide and 1000 ft. long at the surface. The Mexican and Ready Bullion orebodies are approximately 20 ft. thick

and from 500 to 1000 ft. long in horizontal section. These orebodies are situated within a stone's throw of a splendid harbor on a sheltered waterway, which extends for 1000 miles from Puget Sound to Skagway. The most convenient and cheapest transportation facilities are thus provided for coal, timber, and other supplies. Concentrates, in the shape of auriferous iron pyrite, are shipped 800 miles to the Tacoma smelter at a cost of $1.72 per ton. The climate, though rainy, is mild and pleasant, corresponding to that of Scotland or southern Norway. While wages are not low, according to some standards (averaging about 32 cents per hour in actual cost), I believe that labor, owing to its efficiency, is really cheap. In addition to these advantages an abundance of water power is available. Little pumping is necessary in the mines. These external factors are so favorable as to be quite exceptional, perhaps unrivaled.

Internal Factors.—The internal factors are also exceptional. The orebodies are large and firm; standing nearly vertical between pretty solid walls, they came up under the glacial drift in large masses that could be attacked in open pits. The metallurgical problem is the simplest.

Mining these orebodies, therefore, presented to the management the following factors: Several million tons of ore favorably situated for cheap handling, but containing less than $3 per ton. To make the maximum profit, or to make profits at all, required cheap methods both of mining and milling.

These conditions as to mining were met at the beginning by the "milling" method in an open pit; and as to treatment by the adoption of a large, simple, water-actuated stamp mill in which ore could be amalgamated and concentrated in wholesale quantities and at minimum cost. The simple metallurgical treatment proved amply effective, for the ore is thus treated at a cost of 17 to 27 cents a ton with an apparent extraction of 90 per cent.

As the mining proceeded it became increasingly difficult and finally impossible to maintain the required output from open pits and it became again imperative to devise a method of mining, this time underground, that would be cheap enough. It was a broader problem than the first because it involved the question of how much ore could be sacrificed on the one hand and how cheap the mining could be done on the other. It was discovered that about 75 per cent. of the ore could be mined without timbers from large chambers kept full of broken ore, only enough being drawn off at the bottom to afford room for the miners at the top. In the widest deposit this process costs $1.00 per ton and in the narrower bodies $1.20 per ton.

No change being required in milling methods on account of increasing depth the inauguration of the method of mining described seems to have

ALASKA TREADWELL GOLD MINING COMPANY

RECEIPTS AND EXPENDITURES IN DOLLARS PER TON. ALSO CONDITIONS AFFECTING OPERATING COSTS

Year	Total gross bullion and concentrate yield per ton	All expenses per ton				Profits per ton			Per cent. ore from		No. feet		Pounds powder used per ton ore	Per cent. ore milled by		Per cent. Indian labor	Average daily pay all D. island employees	Concentrates		Grand total		Year	Remarks
		Douglas Island		San Francisco, London, Paris, consulting engineer	Total	Operating	Other	Total	Surface pits	Underground	Shaft sunk	Other development work		Water power	Steam power			Per cent.	Value per ton	Tons ore milled	Profit		
		Supplies	Labor																				
1890–1	$3.49	$0.73	$0.85	$0.13	$1.71	$1.71	$0.10	$1.89	100.0	....	...	......	1.01	79.11	20.89	.....	.....	2.66	$40.65	220,686	$418,20[illegible].90	1890–1	
1891–2	2.95	0.65	0.78	0.07	1.50	1.45	0.08	1.51	100.0	....	...	......	0.93	73.29	26.71	.....	.....	2.10	32.08	239,633	361,980.16	1891–2	
1892–3	2.94	0.72	0.56	0.07	1.35	1.59	0.04	1.63	100.0	....	...	......	0.76	70.18	29.82	.....	.....	1.80	41.42	237,235	385,613.79	1892–3	
1893–4	3.21	0.52	0.75	0.09	1.35	1.86	0.10	1.96	100.0	....	...	1607.0	0.73	64.37	35.63	21.34	$3.00	1.84	46.45	220,043	429,948.86	1893–4	
1894–5	2.60	0.59	0.71	0.07	1.37	1.23	0.06	1.29	100.0	....	116	1076.0	0.60	71.34	28.66	15.84	3.15	1.75	50.52	241,278	309,534.56	1894–5	
1895–6	2.97	0.45	0.65	0.07	1.16	1.81	0.07	1.88	99.0	1.0	50	1091.0	0.76	80.56	19.44	13.63	3.10	1.66	57.73	263,670	497,342.22	1895–6	
1896–7	2.80	0.75	0.75	0.07	1.57	1.23	0.11	1.34	95.1	4.9	...	2162.0	0.97	74.66	25.34	14.47	3.25	1.92	48.14	242,027	323,034.95	1896–7	
1897–8	2.32	0.57	0.82	0.08	1.48	0.84	0.12	0.96	89.5	10.5	458	2208.0	0.84	62.73	37.27	8.36	3.23	1.70	44.33	254,329	243,260.82	1897–8	
1898–9	2.71	0.48	0.74	0.07	1.28	1.43	0.12	1.55	85.1	14.9	48	3805.0	1.08	68.46	31.54	12.13	3.13	1.96	48.11	250,408	386,792.34	1898–9	
1899–0	2.07	0.44	0.45	0.03	0.92	1.15	0.06	1.21	67.0	33.0	...	3455.0	0.80	79.97	20.03	5.71	3.02	1.76	38.78	557,960	673,961.18	1899–0	
1900–1	1.88	0.54	0.62	0.03	1.19	0.69	0.08	0.77	47.7	52.3	...	4767.5	1.14	79.29	20.71	5.33	3.25	1.78	41.92	457,802	352,558.89	1900–1	
1901–2	1.91	0.49	0.78	0.01	1.28	0.63	0.05	0.68	56.0	44.0	231	5327.5	1.65	77.39	22.61	5.00	3.26	1.82	50.48	682,893	463,489.93	1901–2	
1902..	1.88	0.46	0.54	0.01	1.01	0.82	0.05	0.87	58.3	41.7	113	2583.0	1.34	84.93	15.07	4.8	3.18	1.88	49.79	508,636	442,513.32	1902	6 months

Alaska United Gold Mining Company—Ready Bullion Mine

RECEIPTS AND EXPENDITURES IN DOLLARS PER TON. ALSO CONDITIONS AFFECTING OPERATING COSTS

Year	Total gross bullion and concentrate yield per ton	All expenses per ton: Douglas Island: Supplies	All expenses per ton: Douglas Island: Labor	All expenses per ton: San Francisco, London, Paris, and consulting engineer	All expenses per ton: Total	Profits per ton: Operating	Profits per ton: Other	Profits per ton: Total	Per cent. ore from: Surface pits	Per cent. ore from: Underground	No. feet: Shaft sunk	No. feet: Other development work	Pounds powder used per ton ore	Per cent. ore milled by: Water power	Per cent. ore milled by: Steam power	Per cent. Indian labor	Average daily pay all D. Island employees	Concentrates: Per cent.	Concentrates: Value per ton	Grand total: Tons ore milled	Grand total: Profit	Year ending Dec. 15
1898...	2.42	$0.71	$0.55	$0.03	$1.29	$1.13	$0.07	$1.19	100.0	......	602	2112	2.69	......	100	.....	$3.34	2.03	$72.00	19,612	$23,412.13	1898
1899....	2.72	0.90	1.04	0.03	1.97	0.75	.....	0.75	37.98	62.02	47	4272	1.32	......	100	9.23	3.08	1.93	38.10	162,107	121,339.75	1899
1900....	2.15	0.78	0.83	0.03	1.67	0.48	.....	0.48	8.42	91.58	259	3552	1.19	......	100	8.50	3.09	2.07	31.57	179,410	86,418.18	1900
1901....	1.94	0.88	0.90	0.03	1.86	0.08	.....	0.08	4.17	95.83	165	2370	1.28	......	100	2.33	3.05	1.97	33.14	170,642	14,476.61	1901
1902....	1.48	0.70	0.78	0.02	1.56	0.02	.....	0.02	1.43	98.57	58	2787	1.19	......	100	1.00	3.10	2.04	32.95	226,522	Loss 5,385.70	1902

700-Foot Claim

Year	Total gross bullion and concentrate yield per ton	Supplies	Labor	San Francisco, London, Paris, and consulting engineer	Total	Operating	Other	Total	Surface pits	Underground	Shaft sunk	Other development work	Pounds powder used per ton ore	Water power	Steam power	Per cent. Indian labor	Average daily pay all D. Island employees	Per cent.	Value per ton	Tons ore milled	Profit	Year ending Dec. 15
1899....	1.72	$0.54	$1.10	$0.03	$1.68	$0.04	.....	$0.04	73.02	26.98	...	1621	1.11	100.0	.....	1.87	$3.04	1.94	$37.87	85,065	$3,405.88	1890
1900....	1.81	0.69	0.84	0.03	1.56	0.25	.....	0.25	49.89	50.11	72	486	1.24	42.58	41.58	3.37	3.01	1.73	34.91	125,612	31,571.05	1909
1901....	1.50	0.90	1.05	0.03	1.97	0.48	.....	Loss 0.42	23.14	76.86	312	1396	1.03	54.16	45.84	1.32	3.11	1.71	28.13	89,450	Loss 32,797.49	1901
1902....	1.33	0.52	0.63	0.02	1.17	0.16	.....	0.16	......	100.0	...	382	0.78	81.82	18.18	....	3.10	1.84	48.46	118,541	19,362.64	1902

Alaska Mexican Gold Mining Company

RECEIPTS AND EXPENDITURES IN DOLLARS PER TON. ALSO CONDITIONS AFFECTING OPERATING COSTS

Year	Total gross bullion and concentrate yield per ton	Supplies	Labor	San Francisco, London, Paris, and consulting engineer	Total	Operating	Other	Total	Surface pits	Underground	Shaft sunk	Other development work	Pounds powder used per ton ore	Water power	Steam power	Per cent. Indian labor	Average daily pay all D. Island employees	Per cent.	Value per ton	Tons ore milled	Profit	Year ending Dec. 15
1894....	$2.79	$0.84	$1.00	$0.13	$1.97	$0.82	.....	$0.82	41.37	58.63	110	795	1.07	53.33	46.67	18.75	$3.70	2.02	$35.45	73,141	$59,639.65	1894
1895....	2.85	0.85	1.03	0.07	1.95	0.90	.....	0.90	48.37	51.63	236	2946	1.08	57.42	42.58	19.48	3.47	2.01	44.84	79,439	71,391.78	1895
1896...	2.42	0.77	0.98	0.06	1.81	0.61	.....	0.61	46.37	53.63	62	2333	1.21	43.39	56.61	26.08	3.49	2.18	42.49	101,702	61,650.43	1896
1897....	2.12	0.69	0.84	0.05	1.57	0.55	.....	0.55	37.76	62.24	...	2130	1.18	62.68	37.32	23.91	3.28	1.81	37.77	158,005	87,101.46	1897
1898....	2.31	0.75	0.90	0.05	1.70	0.62	.....	0.62	34.55	65.45	...	2081	1.25	55.50	44.50	16.46	2.95	2.07	34.80	162,457	100,663.07	1898
1899....	2.09	0.72	0.96	0.03	1.73	0.36	$0.01	0.37	28.84	71.16	302	1910	1.36	48.47	51.53	15.59	2.93	1.98	37.85	166,054	62,233.42	1899
1900....	1.89	0.68	0.97	0.04	1.69	0.20	.....	0.20	16.30	83.70	107	2987	1.24	42.10	57.90	11.49	3.05	1.64	26.07	166,449	33,821.02	1900
1901....	1.90	0.75	0.98	0.03	1.76	0.14	.....	0.14	0.53	99.47	112	5329	1.00	43.97	56.02	0.76	3.07	1.78	39.30	178,960	24,709.63	1901
1902....	2.06	0.62	0.99	0.03	1.64	0.41	.....	0.41	......	100.00	218	4988	1.32	50.60	49.40	.....	3.12	1.83	59.51	207,455	86,025.51	1902

solved the problem of making these ore-bodies pay to an indefinite depth as long as they maintain anything like their present size and value.

The milling of the Treadwell ores, its results, the collection and shipment of concentrates, are all shown up to 1902 in the accompanying tables given by Mr. Kinzie. It is well to note that in each of the mines the value recovered is about equally divided between free gold saved by amalgamation, and auriferous pyrite which constitutes 2 per cent. or less of the original ore. The shipment and treatment of these concentrates costs about $6.75 a ton and when spread over the original ore milled costs from 10 to 14 cents a ton.

The actual results and average costs up to the end of the reports for 1907 for the various mines are as follows:

	Treadwell	Mexican	Ready Bullion
Tons milled	8,485,085	2,447,063	1,841,079
Tons in sight	4,982,883	794,924	1,378,651
Feet development work, 14 years	74,717	59,960	27,362
Tons developed per foot approximate	120	54	100
Total value recovered per ton	$2.44	$2.55	$1.89
Profits, operating, per ton	1.16	0.77	0.25
Total operating cost per ton	1.28	1.78	1.64
Last depreciation figures	0.21	0.23	0.35
Total estimated cost	1.49	2.01	1.99

From the above it appears that the Treadwell and Mexican mines have been very profitable, but that the Ready Bullion has not as yet earned enough to justify the investment, but the improvements in grade at the bottom is such as to be very promising for the future. It further appears that the combined mines have treated 12,773,227 tons of quartz worth $30,446,947 or $2.38 per ton for a total operating cost of $1.43 per ton, to which is to be added 24 cents a ton as a fair estimate (it seems very liberal) of the value of the plants employed; the total to be estimated for cost being $1.67 per ton and the profit 71 cents or 30 per cent. of the gross value recovered.

Below are given, more in detail, the cost of these remarkable mines, for the Treadwell in the year ending May 31, 1907, and for the Mexican and Ready Bullion for the calendar year 1907, the ore all coming from underground stopes except 12 per cent. of the Treadwell ore which came from an open pit. In each case the costs, while not the lowest on record, are quite near the average. I believe in the case of the Treadwell that the costs are overstated, certain sums being credited to the receipts which might logically be deducted from the costs, but I have made no attempt to change the figures given.

	Treadwell	Mexican	Ready Bullion
Tons milled	702,953	214,263	213,370
Cost mining and development	$1.00	$1.19	$1.00
Milling	0.17	0.27	0.36
Shipping and smelting concentrates	0.12	0.12	0.11
General expense	0.04	0.09	0.07
Construction	0.04	0.01	0.01
Total operating	$1.37	$1.68	$1.55
Depreciation	0.21	0.23	0.35
Grand total	$1.58	$1.91	$1.90

Homestake.—From the Treadwell group one naturally turns to the Homestake mine in the Black Hills, South Dakota, to make comparisons. This is the greatest gold mine in the world in point both of tonnage and of gross value produced. In eight years out of the last nine the output has been as follows:

		Per Ton
Tons milled	9,383,114	
Gold recovered	$34,638,518	$3.69
Cost	28,587,300	3.04
Profit	6,051,218	0.65

It is to be observed that the costs are nearly twice as high as at the Treadwell group. Why the difference should be so great does not appear. One is tempted to suspect that the management may have had something to do with it, although nothing is more dangerous than to jump at such a conclusion.

The external conditions are not so favorable as at Douglas Island. The wages are about the same, but there is not such a good supply of water and timber, and transportation is more costly. The cost of water alone is approximately 10 cents a ton at the Homestake.

The internal factors would appear to be about the same. A vast body of silicified slate has been followed from the surface to a depth of nearly 1600 ft. The thickness is several hundred feet. The metallurgical problem seems to be simple; 4.7 tons are crushed per stamp per day. Amalgamation is followed by cyaniding the tailings at the very moderate cost of 18 cents per ton stamped. The finer slimes receive a further treatment not described in the reports.

There are 1000 stamps employed on Homestake ore in six different mills. The whole milling process in 1907 cost as follows per ton:

Milling and amalgamating	44c.
Cyaniding	18c.
Slime treatment and construction	24c.
Total	86c.

The recent cost for mining and development is $2 a ton. For mining at the rate of 4000 tons a day from a single orebody this seems high. Possibly the methods are too good; a more wasteful one might be more profitable. Assuming that with the methods that have been used the profit now averages 75 cents a ton, it is demonstrable that the adoption of a method that would reduce the mining cost from $2 to $1.25 per ton at a sacrifice of 25 per cent. of the ore now saved would increase the value of the mine 60 per cent. If on the present basis 20,000,000 tons would be mined in fifteen years at a profit of $15,000,000, the present value. figuring interest on deferred payments at 4 per cent., would be $11,111,000, On the other basis, 15,000,000 tons mined in eleven years at a profit of $22,500,000 would give a present value of $17,700,000.

Mines of the San Juan Region, Colorado

The external conditions at the Camp Bird property are unfavorable. The altitude of the mine is 11,200 ft. in steep and snowy mountains. In 1906 a snow slide destroyed the mill and delayed operations six months. Wages are about average for the Rocky Mountain region, but it is not to be supposed that men are capable of sustaining their best exertions at such an altitude. Supplies have to be hauled several miles from the railroad station, Ouray, over a steep mountain road often blocked with snow.

The internal factors are as follows: The ore occurs in extensive shoots

Camp Bird Mine for the Year Ending April 30,1908

Blocking out ore	$0.64
Ore breaking	0.60
Timbering	0.69
Loading and tramming	0.78
Hoisting	0.18
Lighting and pumping	0.15
Engineering, sampling, and assaying	0.10
Foremen and bosses	0.17
Power	0.32
Maintenance	0.44
Total mining, 78,966 tons	4.08
Transportation to mill	0.28
Stamp milling 80,087 tons	1.19
Cyaniding	0.61
Shipping and selling concentrates	1.42
General expense, consulting engineer, administration, taxes, etc.	1.50
Depreciation average five years	0.78
Survey of unpatented claims	0.06
London office expense	0.35
Total cost per ton	$10.27

in a nearly vertical quartz vein 3 to 10 ft. thick, in a horizontal formation of bedded porphyries. In a total length of 4500 ft. explored there are four ore shoots aggregating 1700 ft. long. This has involved an expense for development of 76 cents a ton.

Stoping is done as at the Treadwell by breaking the whole vein upward from the levels and drawing out only enough to make room for the miners. Up to April, 1907, about 489,000 tons had been taken out and milled; 112,000 tons remained broken in the stopes.

Total values recovered were $25.90 per ton; of these 74.76 per cent. was obtained by amalgamation; 16.02 per cent. by concentration, and 9.22 per cent. by cyaniding. The extraction of the gold is given at 93.84 per cent. Adopting this as a rough estimate or the total extraction of all metals, we get $27.60 as the original value of the ore, so that the mill losses are approximately $1.70 per ton.

It is interesting to compare this record with that of the Mysore mine in India, which extracts a somewhat lower grade of ore without any expense for the treatment of concentrates, and mined ore during the same year at a cost of $9.25 a ton, although the wages at the Mysore mine seem to have averaged only 36 cents a day. The number of men employed at the Camp Bird is approximately 300 for an output of 80,000 tons, while at the Mysore 8334 are employed for an output of 234,000 tons.

It appears that the operations for the year given above were cheaper than for former years, an explanation being found in the fact that some 17,000 tons of ore were withdrawn from the stopes more than were broken in the stopes, and because the tonnage treated during the year was greater than ever before without any increase in the amount of general expense. During the past three years 184,605 tons were treated, averaging $28.90 per ton, and the earnings were $16 a ton, leaving $12.90 as the actual cost. It is stated that the extraction reported for 1908 was the highest on record. If we assume that the extraction has averaged 92 per cent. the performance of the mine may be calculated as follows:

Assay value of ore	$31.40
Loss in milling	2.50
Yield	28.90
Total operating costs, including construction, development, and London expenses	12.90
Total costs and losses	15.40
Profit per ton	16.00
Percentage of profit	51.00

These costs are much higher than those of the Liberty Bell mine a few miles away. The reason undoubtedly is the higher grade of the Camp Bird ores; this accounts for higher costs in taxes, freight, and treatment, etc., and furnishes the excuse for pretty liberal fees and management.

Results of Operations at the Liberty Bell Mine

Tons mined and milled		510,720
Net receipts per ton		$7.20
Costs:		
General expense	$1.05	
Mining and development	2.65	
Tramming to mill	0.42	
Milling	1.70	
Shipping concentrates	0.36	
Total operating	$6.34	
Depreciation	0.30	
Total		$6.64
Profit per ton		0.56

At this mine 26,446 ft. of opening work has been done in nine years, resulting in mining and developing about 900,000 tons of ore, or 34 tons to 1 ft. The cost per foot of development seems to be about $10, and per ton developed, $0.30. The stoping width is about 5 ft.

Analyzing roughly the difference between the costs of the Camp Bird and the Liberty Bell it appears that the former is more expensive, as follows:

	Per ton
Underground cost	$1.46
Milling	0.15
Treatment charges	1.45
General expense	2.00
Depreciation of plant	0.55
Total	$5.61

It may be fairly said that the higher cost at the Camp Bird for milling and treatment charges are entirely justified by the higher grade of the ore. As to other expenses one may doubt their necessity.

Other mines in the San Juan region whose reports are available are the Tomboy and the Smuggler Union. I have not investigated these reports, but in a general way the costs at these mines are not greatly different from those of the Liberty Bell. These mines have each reported costs lower than those given, for a single year, but it is doubtful if they would be lower if figured upon a long term of years.

In general, mining in the San Juan region costs about $7 a ton. The external factors of a rough surface, a severe climate, costly transportation and a debilitating altitude are all unfavorable. The internal factors are such that only a small tonnage can be maintained. Metallurgically the ores are only fair, and while not markedly difficult, do not seem to permit of full treatment at a cost of less than $2 a ton. The explanation, therefore, of the big jump in costs from $1.50 at the Treadwell and $3

at the Homestake to $7 in the San Juan is the cumulative effect of a variety of both external and internal factors.

El Oro, Mexico

The mines at El Oro, Mexico, are well managed; they pay good dividends and issue good reports. The two principal mines are the Esperanza and El Oro on the San Rafael vein and the Dos Estrellas on a parallel vein to the westward. The Mexico mine just north of the Esperanza on the San Rafael lode is promising. The veins are large mineralized shear zones in slate or shale. There are numerous cross faults. The veins are for the most part obscured by a later flow of andesitic lava which covers the important orebodies to a depth of several hundred feet. The ore is quartz with pyrite sprinkled through it. The gold is very finely divided, and will yield by amalgamation only about 15 per cent.

Grade of Ore and Output.—It appears that the Esperanza mine up to the end of 1908 produced 1,176,117 tons averaging $19 per ton, and El Oro 1,080,000 tons to the end of 1907 averaging $11.39 per ton, in both cases by actual yield. Probably these figures indicate average ores produced by the principal mines in the district. If so, we get a yield of $16.33. It is probable that the extraction has averaged something like 88 per cent., so that the assay value of the ore as mined must be about $18.50 per ton. Two distinct types of ore have been worked; an oxidized cyaniding ore averaging about $13 a ton by assay value, by extraction about $11.40 as stated above for the material mined; and a narrower vein of sulphides discovered and worked on the Esperanza, and lately on the Mexico mine, the ore from which has been treated mainly in the smelters and has been of high grade, much of it running three or four ounces per ton. Below are given the figures for mining and milling at the El Oro and Esperanza up to the end of 1907, since which time the reports indicate nothing to warrant changing them.

In general, the milling ores of the district may be described as follows:

Assay value	$13.00
Loss in milling	1.60
Yield	11.40
Costs mining and milling	7.00
Profit	4.40
Percentage of profit	34.00

Smelting ores produced by the Esperanza in 1906 were:

Value per ton		$74.50
Freight treatment and deductions	$18.75	
Cost of mining per ton	5.00	
Total cost		23.75
Profit		50.75
Percentage of profit		68.00

The external conditions are probably about average for gold mining. The wages for natives are low and their labor inefficient. Water-generated electric power is furnished to the mine. The El Oro company owns a railroad, timber land, and a sawmill, and presumably supplies the other mines as well as its own with timber and transportation.

The walls are heavy, and where broken by cross-faults become very soft. Ordinarily the square-set rooms can be kept open to a height of 40 to 50 ft.; then they must be filled. The mines are pretty hot. The ore forming in good-sized bodies is separated into streaks in different parts of the shear zone. The development of these requires considerable crosscutting and drifting along the intersected streaks. Work is also done on entirely distinct veins separated by some hundreds of feet of waste. The experience to date has shown the requirements in the way of development to be as follows:

	Feet	Tons mined	Tons developed
El Oro	88,803	820,000	605,000
Esperanza	60,640	875,000	142,000
Total	149,440	1,695,000	747,000

About one foot of opening work to 16 tons discovered

	El Oro	Esperanza
Tons mined	1,080,788	450,000
Tons milled	1,027,282	333,330
Mining	$1.99	$2.80
Development	0.74	0.80
Milling	0.77	2.63
Cyaniding	0.74	
Water	0.02	
Other	0.13	......
General	0.90	1.08
Construction	0.36	0.19
Total	$6.02	$7.50

The recovery of metals at the two mines is reported for 1906–7 as follows:

	Gold, per cent.	Silver, per cent.	Total value, per cent.
Esperanza	90.64	57.33	86.20
El Oro	90.28	68.55	86.63

Costs at the Esperanza have always been higher than at the El Oro both for mining and milling. There is nothing in the reports to explain why this should be so.

Kolar District, Mysore, India

In Vol. XXXIII, Part 1, of the "Memoirs of the Geological Survey of India," F. H. Hatch gives an excellent practical description of the Kolar mines as they were in 1900. Since that time certain changes have been introduced, notably water-generated electric power; the scale of operating has increased, and the costs diminished, but no specific description of these changes has come to my attention. The reports of the various companies give abundant information about output, costs, mine developments etc. It is possible that something might be changed by Mr. Hatch if the descriptions were be to brought down to the present day, but on the whole the sources of information are satisfactory. One feels particularly like complimenting Messrs. John Taylor & Sons, who manage most of the mines, on their complete and detailed annual reports to their stockholders.

The principal mines are the Mysore, Champion Reef, Ooregum, and Nundydroog: other mines are not very profitable. The district has been opened since 1882. The output has been steadily increasing, but the maximum seems to have been reached. The climate is tropical; the rainfall averages 30.13 in. per year, but is variable.

This Indian gold-field is one of the most instructive examples to be found anywhere in studying the basic principles of mine economics. The center of the field is 183 miles from the important seaport of Madras; the freight rate for various articles being as follows (presumably per long ton):

Coal in carloads	$1.40
Timber less than 17 ft. long	1.90
Timber more than 17 ft. long	2.24
Steel, cast iron pipes, machinery, and kerosene	3.40
Wire ropes and galvanized iron pipes	4.45
Machinery in small lots	5.87
Explosives	16.67

Indian coal is delivered at the mines for $6.50 per ton; English coal for $9.75, and fire wood for $2.56. Ordinary mining timber costs from $20 to $45 per M., a large proportion being of the more expensive kinds. Dynamite costs about 27 cents per pound and blasting gelatin (93 per cent. nitroglycerin) 35 cents. These supplies, it will be observed, are all more expensive than in the United States in the proportion of perhaps two to one.

Labor at Mysore.—When we come to labor the situation is interesting. Men are employed in the following proportions:

Europeans	2.2 per cent.
Eurasians	1.6 per cent.
Natives	96.2 per cent.

I have no means of computing, except approximately, the average wages earned by three classes. Europeans are paid by the month, on contract usually for three years. Transportation is provided by the companies to and from Europe, and quarters, furniture, fuel, lights, and servants also. Men laid up by sickness draw full pay. The salaries vary from $30 a month for some of the miners to $100 for smiths and machinists, and $250 to the highest paid chemists and foremen. Considering the debilitating effect of the climate and the loss of time during illness, voyages, and holidays, it does not seem improbable that the work done by these men costs at least twice as much as work done in the United States would cost if done by men paid the same wages. Indeed I believe this estimate is too low.

Wages of natives are as follows in cents per day.

Carpenters	12 to 50
Smiths	8 to 48
Timbermen	16 to 43
Engine drivers	20 to 33
Trackmen	20 to 41
Gang bosses	24 to 33
Machine men	20 to 33
Hand miners	16 to 24
Blasters	16 to 24
Landers	16 to 20
Trammers	16 to 18
Muckers	14 to 16
Firemen	12 to 16
Surface coolies	8 to 12

It is, of course, impossible to obtain from these details an exact estimate of the wages paid, but on the assumption that the wages of miners are somewhere near the average for natives and that Europeans average $5 a day including expenses, and Eurasians $2, we have:

2.2 Europeans at $5 equals	$11.00
1.6 Eurasians at $2 equals	3.20
96.2 Natives at $0.23 equals	22.12
100.0	$36.32

This means an average wage of 36 cents or thereabouts, for all employees.

Factors in Mining.—The internal factors are a single marvelously persistent quartz vein, with a few branches, developed for a length of

17,500 ft. The vein occurs in a belt of schists which I suppose, from the presence of beds of quartzite, are undoubtedly in part metamorphosed sediments. The belt seems to be a syncline, but it is invaded on both sides by intrusive granites. The bulk of the schist consists of altered traps or lavas. There are some later dikes of a basic character. The vein corresponds both in strike and dip, which is about 50 to 55 degrees west, with the foliation of the schists. The ore is a clean quartz containing 0.25 per cent. of pyrite. The quartz occurs in a number of shoots along the vein. Some of the shoots occur in sharp anticlinal folds where something like the saddle reefs of Bendigo, Australia, has been developed in the vein. The direction of other ore shoots along the plane of the vein seems to be about parallel to the axes of these folds. The extent of the shoots is variable; some of the largest are known to be more than 4000 ft. deep along the slope, and as much as 800 ft. wide, measured at right angles to the long axis. It is difficult to ascertain the thickness of the vein stoped; the average is probably between 3 and 4 ft. Taking the vein at large, the poor with the good, the average thickness of mill ore developed on the Mysore property in 1907 was 1.8 ft.

Although these mines, particularly the Mysore, are looking exceedingly well in the bottom, the thickness and grade of the ore show some diminution. The greatest vertical depth reached is about 2400 ft. in the Edgar shaft of the Mysore. In earlier years, when the mines were less than 1000 ft. deep vertically, the ore shoots on the Mysore and Champion Reef mines seem to have averaged nearly 5 ft. in thickness.

Method of Treatment.—The milling practice is simple. The ore, when properly sorted, yields a clean quartz with very little clayey matter in it. The process consists of amalgamation in a stamp battery followed by cyaniding the tailings. A special cyanide process is used for the comparatively small proportion of slimes. The only distinctive fact is that the crushing duty per stamp is low, being only 2.25 tons per day per 1050-lb. stamp. The pulp is put through screens averaging about 1600 apertures per square inch. The low stamp duty is made necessary by the high grade of the ore. In the Transvaal and at the Treadwell the duty per day is about five tons per stamp.

A few years ago a striking and uneconomical feature of the metallurgical practice was that the work was done in a number of small mills instead of in a large central one on each property. This bad feature has been, I believe, largely corrected.

It will be seen from the following table that the conditions and costs are fairly uniform for the four properties. Consequently it does not seem worth while to give details for more than one.

For this purpose the Mysore mine serves excellently. It is an extraordinarily good and profitable property, situated at the south end

OUTPUT AND VALUATION OF ORE PRODUCED BY THE FOUR PRINCIPAL MINES OF THE KOLAR DISTRICT OF INDIA REDUCED TO SHORT TONS AND AMERICAN CURRENCY.

Name and date	Tons mined	Tons ore in sight	Yield from ore mined	Average per ton	Dividends	Average dividends per ton	Cost per ton
Mysore 1884–1898	2,484,562	1,085,000	$52,624,000	$21.18	$27,252,000	$10.96	$9.22
Champion Reef 1892–1908	2,130,748	....	40,340,000	19.00	17,148,000	8.05	10.95
Nundyroog 1888–1908	1,029,700	133,000	17,736,000	17.24	7,163,000	6.96	10.28
Ooregum 1888–1908	1,660,781	172,000	23,580,000	14.20	7,852,000	4.74	9.46
Four mines 1884–1908	7,305,791	1,388,000	$134,300,000	18.40	59,655,000	8.18	10.22

NOTE.—There is reason to believe that the dividends are larger than the real profits because they include sums obrained from stockholders, for premiums and new stock issued to cover new construction and developments. This practice, however, has now been stopped and it may that the costs estimated are not far from the truth, on the theory that the money heretofore spent on plant will serve for the future operation of the mines, or at least for the ore in sight.

of the district and covering 7700 ft. along the lode. It is developed to an extreme vertical depth of 2600 ft., equal to 4000 ft. along the incline. The ore is derived from three independent shoots of which the central one is the more prominent, but all three have proved persistent to the lowest workings. In 1907 the record was as follows, expressed in short tons and American currency:

Tons mined and treated	233,825
Assay value of ore	$20.00
Yield of ore	17.12
Loss in milling	2.88
Extraction in mill	85.51 per cent.

	Costs per ton
Plant and equipment, including a proportion of the work, average for eleven years	$1.87
Administration	0.20
Mining	4.68
Milling	0.63
Cyaniding tailings	0.23
Repairs to buildings, machinery, and plant	0.90
Surface costs	0.10
Pumping charges	0.05
Transport and insurance of gold	0.15
Kolar Central Metallurgical Establishment	0.01
Medical Establishment	0.04
Survey department	0.01

Police and detective force	0.01
Traveling expenses of employees	0.04
Kolar Gold Field Electricity Department	0.01
Telegrams, postages, and incidental expenses in India	0.02
Directors' fees	0.11
Salaries and bonuses to managers and clerks	0.15
Telegrams, postage, stationery, etc	0.03
Total costs equalizing small differences in details	9.25
Net profit per ton	7.87
Profit on gross value of ore mined	39 per cent.
Total costs and losses	12.13

A Question of Bookkeeping.—To charge improvements to capital account, even if they are absolutely new, is a bookkeeping error into which nearly all mining companies fall. This error is, of course, in most cases theoretically rectified by writing off a certain amount of depreciation. While in the case of these Kolar mines it appears that the depreciation has kept pace with the increase of capital (for eleven years the Mysore company received from stockholders about £60,000 a year), this does not alter the fact that the money thus written off did not come out of the mine. To some extent, of course, the money thus provided was used to make a real increase in the company's resources, and to this extent it will be paid back in the shape of increased profits, or lower costs, in later years. But it should never be forgotten for a moment that there is always some work going on about a mine in the shape of permanent improvements, and that for a period of years the average amount thus expended should not be written off the balance sheet; it should be charged to operating. To pay operating expenses out of new capital is either a fraud or a bookkeeping sophistry. It is always a mistake more or less complete. It may be partly justified but never wholly.

The accompanying table prepared by Mr. Hatch shows the distribution of costs for the year 1899. These costs are a little higher than the average, but not so much as to give a seriously false impression.

Within the past year or two considerable economy has been effected by the introduction of water-generated electric power from the Cauvery falls. In 1899 steam power cost $150 per horse-power year and the cost per ton for the power used was more than $3. Electric power is now furnished for $90 a year, reducing the power cost more than $1 per ton.

I will not go into details regarding all the mines, but will give some further facts regarding the Mysore, the largest and best mine in the district. This property in the years 1902–1907, inclusive, did 163,691 ft. of development work, mined and milled 1,210,000 tons of ore, and increased its reserves from 380,800 tons to 1,012,480 tons. The actual ore developed during the period was 1,841,500 tons, being a trifle more than 11 tons per foot of development work. This development with approximate costs was made up as follows:

Drifts and crosscuts, 117,912 ft. $10 equals	$1,179,120
Raises, 24,041 ft. at $40 equals	960,000
Winzes, 12,291 ft. at $40 equals	490,000
Shafts, 9,447 ft. at $100 equals	944,700
Total	$3,574,000

The costs are approximations from Hatch's report.

Cost at the Mines of Mysore in 1899, According to Hatch

	Mysore	Champion reef	Ooregum	Nundy-droog	Balaghat	Coro-mandel
Mine costs	$5.79	$7.15	......	$7.02	$12.12	$4.87
Mill	1.28	1.68	......	1.41	1.41	1.60
Wheeler pans	.....	0.69	$9.46	0.21	.....	.....
Cyanide	0.69	0.89	....	0.75	0.50	0.47
Administration	0.28	0.27	0.44	0.51	0.79	0.76
General charges	0.75	0.61	0.49	0.48	0.31	0.49
Total	$8.79	$11.29	$10.39	$10.38	$15.13	$8.19
Royalty on gold ore	1.58	1.51	0.86	1.12	0.63	0.21
Depreciation	0.41	0.26	0.14	0.40	2.20	0.50
London office	0.39	0.30	0.33	0.65	0.88	0.74
Grand total	$11.17	$13.36	$11.72	$12.55	$18.84	$9.64
Reduced to short tons	$10.00	$11.93	$10.47	$11.21	$16.82	$8.61

High Development Cost.—If these costs are anywhere near the actual, and I believe that they are, we have an average cost per ton developed of about $1.94 and per ton milled of $2.95.

In the abstract of Hatch's figures for various kinds of work it is to be observed that the development accounts for about half the cost of mining. In this connection, however, it is well to point out that a considerable portion of the development work does not appear in the working costs, but is charged to capital account. The only place where this expenditure appears is in the balance sheet where certain sums are "written off" for depreciation, etc. These sums amount in six years to $2,122,000 on machinery, plant, etc. Of this a good deal must represent the cost and equipment of Edgar's and other shafts.

To show how this bookkeeping works, let us take the revenue account for the year 1907. Here we find that administration and working costs, including directors' fees, insurance, and all general expenses, amount to $8 per ton. To this we must add from the balance sheet, in order to get the management's real estimate of the costs, the sum of $1.76 per ton for depreciation, this being the average for the last six years. With this addition the total cost is $9.76. This, it will be observed, is very close, both to Mr. Hatch's figures in 1899, and to my own estimate based on the output and dividends.

Mr. Hatch comments as follows:

"The working costs are high, but there is not much difficulty in accounting for this. First, the nature of the ore deposit dictates a high cost of working, as, for instance, the occurrence of the pay-ore in shoots, which, though of high grade, are of comparatively limited extent. This leads to a heavy expenditure in development, as much sinking, driving, and crosscutting must be done in waste rock in order to open up pay or shoot ore. The cost of this development work is included in the figures given for working costs. Then again the heaviness or instability of the ground in parts of the mines necessitates a big expenditure on timber to secure the stopes, shafts, and levels.

Cost and Grade of Ore.—"Further, it must not be forgotten that the cost of working a high-grade ore is of necessity greater than that of a low-grade ore, and the reason for this is plain. In mining low-grade stuff the main object is to obtain a large tonnage at a low cost; consequently the stopes are carried as wide as possible and the whole mass of the orebody is, as a rule, exploited, the exploratory or dead work being at a minimum. With high-grade stuff, on the other hand, the stopes are kept as narrow as possible, and great care is exercised only to extract the payable portions of the ore-body. Much exploratory work in waste rock is, therefore, necessary in order to locate the pay ore. Similar factors influence the metallurgical treatment. With low-grade stuff the ore is passed quickly through the mill, a high stamp duty being maintained by the use of coarse screening and a low discharge, and the cyanide process is relied upon to catch the gold that escapes amalgamation. Whereas with high-grade ore the usual practice is to crush fine, and to catch as high a percentage of the gold as possible by amalgamation.

"For these reasons it is impossible to compare the working costs of high-grade mines, such as those at Kolar, with the low-grade mines of other countries, as, for instance, those of the Witwatersrand in the Transvaal. At the same time, it must be admitted that a reduction in working expenses at Kolar could no doubt be effected by improvements in milling plant, and by the substitution of automatic mechanical means for native labor in the handling of the ore delivered at the shaft top, and of the tailings leaving the mill. The substitution of a large centrally-placed mill with heavy stamps for several small and scattered mills with light stamps, which at the present moment is being carried out on the Champion Reef, and is in anticipation at Ooregum, will decrease the cost of milling at these mines. The introduction of mechanical haulage, automatic sorting tables, tailings, wheels for elevating the tailings, and pointed boxes for classifying and filling directly into the cyanide vats, all these improvements would no doubt have a similar effect. So also will the introduction of water power transmitted by electric current, as it is proposed to do by the Cauvery power scheme."

Details of Development Costs, Hatch

Cost of Raising (10 × 5 ft.) 15.6 ft. per month

Labor, white	$8.25
Labor, native	4.50
Explosives	6.25
Supplies	4.90
Compressed air	21.00
	$44.90

COST OF DRIVING

Hand	\$9 per ft., rate 15 ft. per month.
Machine	\$11 per ft., rate 30 to 35 ft. per month.

Stoping in 4½-ft. vein without timbering costs about \$1.25 per ton.

COST PER FOOT OF SHAFT-SINKING IN KOLAR GOLDFIELDS

	Nundydroog 12 × 6 ft.	Oakleys' 16 × 8 ft.	Champion Reef 16 × 8 ft.	Edgar's Mysore circ'r 18 ft.
Labor	\$31.27	\$32.68		
Timber	7.88	25.22		
Explosives and supplies	13.40	24.20		
Compressed air	32.84	33.88		
Hoisting	10.93	4.84		
Drill sharpening	0.49			
	\$96.81	\$120.82	\$145.91	\$120
Speed per month	15 ft.	25 ft.	28 ft.	20 ft.

Equivalent work in the United States may be estimated as follows:

Sinking large working shafts (Lake Superior, Butte, Cœur d'Alene, or Cripple Creek), average rate per month 50 ft., cost per ft.	\$100
Raising with complete timbering, 10 × 6 ft.	25
Drifting in average ground, 5 × 8 ft.	9

Wages and Cost of Labor.—I have given many details about the Kolar mines because I wish to illustrate the extraordinary lack of correspondence between the wages paid and the costs. There does not seem to be any detail in which work at these mines is done cheaper than in the United States. In Cripple Creek, or Butte, or the Cœur d'Alene, where wages average ten times as high as at Kolar, work can be done just as cheaply. This is true of drifting, of crosscutting, of raising, of shaft sinking, of stoping, of everything on which I can find data for comparison.

It is true that supplies cost more than in the United States; nevertheless out of working costs of \$8.96 per ton I find that labor must account for about \$5.50 or 60 per cent. This is the usual proportion in the United States. We find that the number of men employed to mine and mill 217,770 tons of rock in 1907 at the Mysore mine was 8334 or 26 tons per man per year. At the Camp Bird mine in Colorado, where external conditions are unfavorable, the ore being of higher grade and the costs nearly the same, the wages are ten times as high and the output per man ten times as great.

It is inconceivable to me that the energy expended by a miner in Colorado is ten times as great as that expended by the Indian miner. The true explanation of the wonderful difference in performance lies in

the industrial efficiency of the community by which the men are surrounded.

THE RAND

Witwatersrand.—The great gold-mining field, Witwatersrand, produces one-third of the world's annual yield of gold, and is so well known to the mining public, and even to the public at large, that any general description of it, other than such as will serve my purpose of illustrating the factors governing the cost of mining, is unnecessary.

The occurrence of the ores here bears a resemblance to that of two important districts described elsewhere, *i.e.*, to the copper conglomerates of Lake Superior and to the Kolar mines in India. Like the Calumet conglomerate the banket beds of the Transvaal are mineralized sedimentary beds, and the value of the material worked is not far from equivalent, but the "Rand" beds are thinner, more persistent, and workable over much greater areas. The Kolar mines, while on a vein of different geological origin and producing ores of much higher value, bear a considerable resemblance in the persistence and abundance of the mineralization.

Two recent papers by distinguished American engineers throw excellent light on the present condition of the industry. Ross E. Browne has written an exhaustive discussion of "Working Costs of the Mines of the Witwatersrand" (republished in the *Mining Journal* of London, in the issues of July, 1907) and Thomas H. Leggett (*Trans.* A. I. M. E., February, 1908), describes the "Present Mining Conditions on the Rand."

Mr. Browne sizes up average conditions for the whole district as follows:

	Per ton milled
Working cost	$5.85
Capital redemption	1.22
Total expense	$7.07
Yield	8.71
Profit	1.64

By capital redemption, I suppose, Mr. Browne means all capital, including probably large sums paid for mining claims. By the theory of costs used in this article such sums are profits paid to somebody by the working of ore from the land and are not, therefore, costs. Accordingly, Mr. Browne's estimate of the cost of capital redemption is somewhat high.

A summary of the record of the Witwatersrand is as follows:

Tons milled (1884–1908)	113,600,000
Value recovered	$1,049,000,000.00
Dividends paid	273,655,000.00
Yield per ton	$9.23
Dividends per ton	2.41
Cost per ton	6.82

In 1908 the figures were as follows:

Tons milled	18,000,000
Value recovered	$144,600,000.00
Dividends paid	41,800,000.00
Yield per ton	8.03
Dividends per ton	2.30
Cost per ton	5.73

It is probable that the dividends in these tables include sums that should properly be charged to redemption of capital, *i.e.*, amortization of plants, and that the costs should be estimated a little higher. On the other hand, it is certain that these costs include all current construction, or depreciation charges, and are a much better exhibit of the real dividend costs than the "working costs" ordinarily published. Almost all the production comes from dividend-paying mines.

On nine representative mines in the district Mr. Browne finds the following average working conditions:

Number of stamps operating	111
Working costs per ton milled	$5.19
Percentage rejected by sorting (probably at surface only)	13
Ratio of tons developed to tons mined	0.90
Width (thickness) of stopes in inches	69
Continuity of reefs, normal for the Rand, unrivaled elsewhere.	
Average depth of mining in feet	1200
Dip of reef	30 degrees
Hardness of ground, solid quartzite and slate.	
Cost of timber per ton of ore mined	4 cents
Cost of coal per ton delivered at plant	$3.41
Gallons of water pumped from mine per ton of ore milled	313
Duty of stamp, tons milled per 24 hours	4.85

With the above average conditions the average costs are as follows:

Development cost per ton	$0.37	
Other mining costs	2.63	
Total cost per ton hoisted		$3.00
Milling, crushing, and amalgamating		0.69
Cyaniding		0.64
General expense at mines		0.25
General expense at head office		0.18
Total		$4.76

These figures represent the costs as they would be if all the ore hoisted were milled, but as 13 per cent. is rejected by sorting, the cost as divided by the tonnage actually milled is brought up to $5.19.

A Comparison of Records.—I cannot believe that these figures make a disadvantageous comparison with costs of similar operations elsewhere.

This opinion is somewhat at variance with the general idea among mining men, and, as I have never been in South Africa, it is perhaps well to explain that I am going wholly upon the consideration of the basic principles involved.

Mr. Browne sees hope of reducing costs to about $3.75 per ton by increasing the efficiency of white labor, by better direction of colored labor, and by reducing the cost of supplies. With this hope I certainly have no quarrel and it is probably not altogether extravagant. Considerable improvements are brought about by necessity and by long-continued effort. As the grade of ore diminishes the cost is inevitably diminished by the simple process, among other things, of refusing to work ores that present difficulties beyond a certain limit. But as a matter of practical experience, taking into consideration all the ins and outs, good luck, and bad accidents, it seems to me that the performance of the Rand mines is fully as good as that of other mines.

To judge better of this let us look up the life history of the greatest of the Transvaal mines, the Robinson, and see how it compares with other great mines of which we have the records.

Robinson Gold Mining Company, to End of 1906

Tons milled		2,657,768
Total value, $46,535,000	Per ton,	$17.50
Working cost per ton		6.36
Construction and improvements		0. 8
Total cost per ton milled		7.14
Profit $27,680,000	Per ton	10.36
Dividends and cash in profit loss		24,219,000
Real estate, securities, and cash on hand		3,461,000

Nearly 60 per cent. of the entire gross revenues is shown as clear profit. Few mines of this grade can equal this showing of costs.

It would be an exceedingly laborious compilation to get the average costs in detail, so I shall content myself with giving the details in a year of which the costs approximate the average. Such a year is 1897 when the total cost was $6.09 divided between working cost at $6.65 and construction at $0.25. In this year the tonnage hoisted was 203,597 of which 23,197 was sorted out on the surface. In addition the amount sorted out underground was estimated at 60,000 tons, making the total stoped about 263,500 tons. Since the sorting out of this waste underground serves no useful purpose in protecting the safety of the workings, it was sorted out entirely to avoid the expense of milling. It is probable that the sorting on the surface and stowing of waste underground cost fully as much as the tramming of ore for the mill. For comparing the work done here with certain other mines it is necessary to make these correction.

These figures are as low as those of the Portland mine at Cripple Creek, figured on the same basis; they are not far above those of the

MINING COSTS, ROBINSON GOLD MINING COMPANY

Tons		Per ton
263,500 stoped	$443,694	$1.68
263,500 trammed	21,882	1.08
203,597 hoisted	19,671	0.10
263,500 mine maintenance and pumping	47,306	0.18
320,000 developed	178,334	0.56
		$2.60

Tamarack, or the Calumet & Hecla, where the volume of material in the same area is more than double, and lower than equivalent work in the Mysore mine. It is to be remembered that the mining is done at the Robinson on two beds, the Main Reef Leader of a payable width of 18 in. and the South Reef of a payable width of 42 in., on which there is not room for working. The effort is to carry the stopes as narrow as possible.

MILLING COSTS

	Tons	Total	Per ton
Crushing and sorting	203,597	$18,134	$0.09
Transport to mill	180,400	5,465	0.03
Milling and maintenance	......	78,548	0.43
Power	......	40,094	0.22
			$0.77

SECONDARY TREATMENT

Vanning, concentration	14,966	$0.07
Cyaniding, chlorination	126,470	0.70
		$0.77
Total treatment		$1.54

Here we have ore worth $20 a ton treated with an extraction of 89.3 per cent. at a cost that seems low enough. A certain correspondence obtains here as elsewhere between the value of ore treated and the cost of treatment, even by the same process.

ROBINSON, GENERAL EXPENSE, 263,500 TONS

	Total	Per ton
General maintenance	$21,071	$0.08
General charges	73,918	0.28
Machinery, plant, and buildings	95,716	0.36
Special charges	23,531	0.09
Construction	46,038	0.18
		$0.99

If all the rock broken, therefore, were treated, we should find the following comparison with the costs as given:

	Per ton milled (as given)	Per ton mined
Mining	$3.90	$2.60
Treatment	1.57	1.54
General expense	1.18	0.81
Construction	0.25	0.18
	$6.90	$5.13

The gradual diminution both of costs and the grade of ore is shown as follows:

	Yield per ton	Working costs per ton
1890	$46.20	$10.02
1906	13.84	5.30

At the end of 1906, 2,180,000 tons of ore were blocked out, of which the development had been paid for by mining operations to date. The average assay value of the reserves was $14.50 per ton, and the extraction being realized was 93 per cent.; so that a net yield of $13.50 could be expected. It seems plain from the steady reduction of costs that these reserves could be mined for all working and construction costs for $5 a ton, leaving a net profit of $8.50 per ton, or $18,500,000.

I feel that this record of the Robinson mine shows, in a general way, the achievements and tendencies of the Rand industry; and that it is a monument, not of extravagance and carelessness, but of excellent engineering and of broad-gaged and honest management.

With this view of the cost problem on the Rand, Thomas H. Leggett is in full accord. I quote from his paper on the "Present Mining Conditions on the Rand," as follows:

"As the mining camp grows older the working costs almost invariably decrease, providing the camp maintains a healthful activity with advancing years, and this has been the case on the Witwatersrand, the result being as follows:

1898, average working costs of 65 companies	25*s.* 1.3*d.*
1899, average working costs of 24 companies (*a*)	25*s.* 2.7*d.*
1906, average working costs of 58 companies	22*s.* 1.0*d.*
1907, average working costs of 56 companies (*b*)	20*s.* 8.0*d.*

a The Boer war broke out in October, hence the records are incomplete.

b Two less than in 1906, due to exhaustion of the Bonanza mine and incomplete records from one other mine.

"These costs include mining, development, crushing, and sorting, milling, cyaniding, maintenance, and general expense, but they do not cover depreciation and amortization, these items being more properly dealt with by the directors at the end of the year. These results show the very material decrease of 4*s.* 6*d.* per ton since 1899, and are, therefore, approaching now to the 6s. reduction predicted by John Hays Hammond in 1901, but it has taken time to attain this result, as I then pointed out it would do. A comparison of the costs in 1907 with those of 1906 shows a decrease of 1*s.* 5*d.*, or 34 cents per ton, due chiefly to decreased wages and increased efficiency of both white and colored labor, including the Chinese in the latter category, though increased crushing capacity through the use of heavier stamps (up to 1670 lb. per stamp) and regrinding in tube mills have also aided.

"In 1906 fifty-eight companies mined and milled 13,065,624 tons of ore at a total cost of £14,411,219, while in 1907 fifty-six companies milled and mined 14,861,234 tons at a total cost of £15,35.,749, being an increase of 1,795,610 tons for an increased cost of only £940,530.

"Most of these economies were attained during the latter half of 1907, after the white miners' strike, and some mines made startling reductions, as, for instance, the Robinson, which reported costs of 14*s.* 9*d.* for November, and the Glencairn, of 15*s.* 1*d.* per ton.

"Such strenuous and successful efforts are now being made to reduce still more the working costs on the Rand, that I think it safe to anticipate another large decrease for the year 1908."

Labor Cost not Excessive.—I have expressed the opinion that costs on the Rand are not essentially different from those that would be obtained were the properties situated in the United States. What about wages? The only direct information I have is the statement of Mr. Browne that whites average $4.60 a day and colored laborers $0.66 per day, and are employed in the proportionof 9.2 colored men to one white m .

Average wages about $1.18 per day; as the percentage of colored men varies, so the average wages will vary from time to time.

In my judgment the figures demonstrate that the Rand is another proof of the fact that the rate of wages does not determine the cost of labor. Criticism of the Rand has been to the effect that costs are higher there than in the United States. Mr. Browne believes that California labor paid California prices on the Rand would be cheaper than the labor

Costs

	Per Foot
Rand, average for shafts, drifts, raises, etc	$20
Kolar, average for shafts, drifts, raises, etc	22
Cripple Creek, average for shafts, drifts, raises, etc	14

Wages

	Per Day
Rand	$1.18
Kolar	0.36
Cripple Creek	3.40

actually employed by about 15 per cent. In California wages are approximately \$3 per day. I have estimated average development costs at various places as shown above:

An exact comparison cannot be made, because the rocks and conditions are different. In the Rand the rock is harder than at Cripple Creek, and the openings probably average larger, but on the other hand, there is less water to pump.

Efficiency of Labor a Function of the Cost.—The point I am seeking especially to bring out is that criticism has been applied to the inefficiency of Rand labor as if it were a special case, and that because wages average low on the Rand costs ought to be correspondingly low. I contend that this assumption, if carried beyond certain narrow limits, is an incorrect one, and if established it would be in opposition to a general economic law.

President Roosevelt's great work has often been called a reaffirmation of the Decalogue. I am afraid that the conclusions I have arrived at are of the same class. You will remember the scriptural phrase, "The laborer is worthy of his hire," and the common proverb that the "Workman is known by his tools." These statements contain the essence of the problem of the cost of labor, always the fundamental and final element in the cost of anything. The gist of the whole subject was tersely stated by the first Lord Brassey, the great English contractor, who said that the same work costs the same money anywhere regardless of the price of wages. The workman, the tools, and the wages go hand in hand. Good wages command through competition, effective workers. Good workmen create efficient tools.

On the other hand, it is a truism to say that high-class tools and machinery can only be used by men who have intelligence enough to secure the wages their efficiency justifies. Where a man's idea of moving dirt is to fill a basket with his hands and carry the basket on his head, his wages correspond with the fruitfulness of his idea; he earns 10 cents a day. Where dirt is moved by the complex organism of modern civilized industry which applies external power through the agency of railroads and steam shovels, the men who operate the tools are better paid. The master of the industrial enterprise, which may be described as the greatest tool of all, a mechanism fashioned by the combined efforts of countless brains to direct the united efforts of men and energy to useful work, is pretty sure to be a millionaire; the man who runs the steam shovel gets \$5 a day; the laborer who moves the ties in front of the steam shovel gets \$2 a day. In the world's market the product is worth the same thing whether it is the result of an industrial miracle or of infinite but stupid human labor. When mankind produces efficiency it gets a due return for it, a return which is expressed pretty accurately in wages.

A Rule Without Exceptions.—The only reason why these conclusions are not accepted as truisms is that people are suspicious of each other

and are accustomed to doubt the fairness of the distribution of wealth. That this distribution is a matter the fairness of which can only be guaranteed by ceaseless vigilance, it is a folly to doubt; but on the whole I believe every body concerned *does* exert vigilance, a vigilance made instinctive by the fundamental laws of the evolution of life, and on the whole, the distribution is pretty fair. To avoid possible errors, however, we had best perhaps not apply this generalization to work of an ephemeral character but only to permanent or semi-permanent industries where labor has time to adjust itself to competition.

But here we have to meet the question, Are not modern methods employed in South Africa and India? Have we not sent there our best engineers, our most modern machinery, and our best methods? If so, then why are not the men more efficient and the wages higher? I answer that it is indeed true that we have sent many cilivized appliances to those places, but not all. Among the things we have not sent are the surroundings, point of view, ambition, and energy of a civilized community. The few hundred or few thousand Europeans who operate mines in Africa or India are immersed in an ocean of black humanity, upon which the small foreign community has an influence, true enough, but not such an influence as to revolutionize the habits, aims, and expectations of the natives..

An enterprise so situated must take into account at the beginning the state of mind of its future employees, and it would be silly to make such plans as might run counter to their prejudices; and, even if the manager hopes to make the natives eventually as effective as Europeans, he would have to plan his operations on a different basis. As a matter of fact, such an expectation is hopeless; an individual Kafir or Hindoo may fill a certain position as effectively as an European, but to expect a large body of such people to become collectively as effective as a body of Europeans whose ideas had been trained for generations along lines making for an entirely different standard of effort is quite absurd. A considerable body of whites may indeed supply a certain amount of mental and nervous energy to the natives which the latter could not supply for themselves, but in so doing the white men must use up energy in the direction of others that they might otherwise use in their own labors.

If a body of colored men in a colored man's country is going to turn out work under the direction of white men as cheaply as the white men can do it themselves in their own country, they must do it by working for lower wages. This is exactly what happens in every case. It is a rule to which there are no exceptions.

Note in 1919.—This chapter has been left as it was. In no other metal have there been so few vital changes. In regard to the Transvaal one pertinent remark may well be quoted from the "Mining Magazine" of London—"about 60 per cent. of working profits are available for

dividends." This is something that applies to all mines and all forms of business in varying degrees, of course, in particular cases. But a large part of so-called earnings are absorbed in various projects, overhead expenses and taxes.

PRODUCTION OF GOLD IN THE TRANSVAAL

	Rand, oz.	Elsewhere, oz.	Total, oz.	Value
January, 1918	694,121	19,991	714,182	£3,033,653
February	637,571	22,188	659,759	2,802,477
March	677,008	19,273	696,281	2,957,614
April	697,733	19,366	717,099	3,046,045
May	720,539	20,778	741,317	3,148,915
June	708,908	18,788	727,696	3,091,058
July	716,010	20,189	736,199	3,127,174
August	719,849	20,361	740,210	3,144,211
September	686,963	21,243	708,206	3,008,267
October	667,955	11,809	679,764	2,887,455
November	640,797	17,904	658,701	2,797,983
December	630,505	10,740	641,245	2,723,836
Year 1918	8,197,959	221,734	8,419,693	35,768,688
January, 1919	662,205	13,854	676,059	2,871,718
February	621,188	15,540	636,728	2,704,647
March	694,825	17,554	712,379	3,025,992
April	676,702	18,242	694,944	2,951,936

NATIVES EMPLOYED IN THE TRANSVAAL MINES

	Gold mines	Coal mines	Diamond mines	Total
January 31, 1918	176,424	11,469	4,715	192,608
February 28	181,066	11,243	4,825	197,134
March 31	183,055	11,076	4,745	198,876
April 30	182,492	11,322	4,753	198,567
May 31	179,879	11,211	4,773	195,863
June 30	179,028	11,473	4,747	195,248
July 31	178,412	11,790	5,011	195,213
August 31	179,390	11,950	4,954	196,294
September 30	179,399	12,108	4,889	196,395
October 31	173,153	11,824	4,749	189,726
November 30	160,275	11,826	4,016	176,117
December 31	152,606	11,851	3,180	167,637
January 31, 1919	160,599	11,848	3,539	175,986
February 28	172,359	11,868	4,264	188,491
March 31	175,620	11,168	5,080	191,868
April 30	175,267	11,906	5,742	192,915

COST AND PROFIT ON THE RAND

Compiled from official statistics published by the Transvaal Chamber of Mines. The profit available for dividends is about 60 per cent. of the working profit.

	Tons milled	Yield per ton		Working cost per ton		Working profit per ton		Total working profit
		s.	d.	s.	d.	s.	d.	
January, 1918	2,167,411	27	1	20	7	6	4	£703,665
February	1,946,338	27	8	21	7	5	11	577,396
March	2,107,561	27	1	21	4	5	8	596,109
April	2,181,609	27	0	20	8	6	2	670,871
May	2,237,644	27	3	20	6	6	5	716,963
June	2,124,205	28	2	21	0	6	11	736,694
July	2,167,869	27	10	21	2	6	6	702,360
August	2,158,431	28	1	21	7	6	3	676,146
September	2,060,635	28	2	22	0	5	10	600,330
October	2,015,144	28	0	22	5	5	3	531,774
November	1,899,925	28	5	23	1	5	1	480,102
December	1,855,991	28	7	23	0	5	6	507,860
Year 1918	24,922,763	27	11	21	7	6	0	7,678,129
January, 1919	1,942,329	28	9	23	0	5	8	547,793
February	1,816,352	28	9	23	2	5	6	498,204

PRODUCTION OF GOLD IN RHODESIA AND WEST AFRICA

	Rhodesia		West Africa	
	1918	1919	1918	1919
January	£253,807	£211,917	£107,863	£104,063
February	232,023	220,885	112,865	112,616
March	230,023	225,808	112,605	112,543
April	239,916	213,160	117,520	109,570
May	239,205	....	126,290	
June	225,447	....	120,273	
July	251,740	....	117,581	
August	257,096	....	120,526	
September	247,885	....	115,152	
October	136,780	....	61,461	
November	145,460	....	108,796	
December	192,870	....	112,621	
Total	2,652,250	871,770	1,333,553	438,792

Transvaal Gold Outputs

	April, 1919	
	Treated, tons	Value
Aurora West	13,800	£ 13,640
Bantjes	......	......
Barrett	......	674
Brakpan	47,500	88,908
City & Suburban	17,342	28,374
City Deep	48,500	97,209
Cons. Langlaagte	45,000	55,546
Cons. Main Reef	47,300	7,753
Crown mines	158,000	217,122
Durban Roodepoort Deep	25,200	35,025
East Rand P.M.	110,000	138,201
Ferreira Deep	32,300	56,264
Geduld	42,000	61,920
Geldenhuis Deep	47,500	54,081
Ginsberg	10,520	10,081
Glynn's Lydenburg	3,970	7,217
Goch	16,600	11,926
Government G.M. Areas	116,000	204,450
Heriot	10,610	14,678
Jupiter	21,200	23,636
Kleinfontein	57,900	71,179
Knights Central	20,000	29,963
Knights Deep	82,900	70,507
Langlaagte Estate	40,000	52,331
Luipaard's Vlei	20,000	
Meyer & Charlton	13,640	39,396
Modderfontein	82,000	173,162
Modderfontein B	54,000	121,206
Modderfontein Deep	41,100	88,943
New Unified	12,000	11,855
Nourse	38,100	53,824
Primrose	19,000	17,159
Princess Estate	19,400	25,382
Randfontein Central	138,000	162,705
Robinson	36,300	41,812
Robinson Deep	45,300	61,750
Roodepoort United	24,200	22,835
Rose Deep	53,000	62,860
Simmer & Jack	46,800	45,652
Simmer Deep	38,600	38,789
Springs	34,940	67,297
Sub Nigel	9,519	24,158
Transvaal G.M. Estates	14,980	23,812
Van Ryn	35,150	33,374
Van Ryn Deep	47,400	103,559
Village Deep	43,400	62,547
Village Main Reef	17,700	22,935
West Rand Consolidated	32,000	37,718
Witwatersrand (Knights)	32,500	40,733
Witwatersrand Deep	......	......
Wolhuter	28,500	35,385

West African Gold Outputs

	April, 1919	
	Treated, tons	Value
Abbontiakoon	8,002	£16,217
Abosso	7,100	12,255
Ashanti Goldfields	8,139	8,862
Prestea Block A	14,930	24,803
Taquah	5,100	14,234
Wassau	......	4,108

Rhodesian Gold Outputs

	April, 1919	
	Treated, tons	Value
Antelope	3,200	£ 4,722
Cam & Motor	......	......
Eldorado Banket	4,021	10,233
Falcon	14,522	28,036*
Gaika	3,066	5,310
Globe & Phœnix	5,754	7,976†
Lonely Reef	4,640	24,434
Rezende	5,300	13,597‡
Rhodesia, Ltd	345	1,271
Shamva	56,595	33,916
Transvaal & Rhodesian	1,800	5,400
Wanderer	10,070	3,286

* Gold, Silver, and Copper. † Ounces Gold. ‡ Gold & Silver

CHAPTER XXVIII

CRIPPLE CREEK, KALGOORLIE, AND GOLDFIELD

Development of Cripple Creek and Kalgoorlie—The geology of Cripple Creek—Estimate of aggregate results—Portland Mine—Kalgoorlie—The costs of five prominent mines—Comparison of Cripple Creek and Kalgoorlie—Goldfield, Nevada—Goldfield Consolidated Mines Co.—Estimate of costs.

Cripple Creek and Kalgoorlie

These two important gold-mining districts were discovered and opened on opposite sides of the globe at about the same time, shortly after 1890. Their appearance added greatly not only to the output of the yellow metal but also to the interest in mining enterprises. It was confidently believed for a number of years that they represented a type of ore deposits that had before been overlooked on account of their refractory nature and their elusive non-spectacular appearance; in other words, because they were hard to treat and hard to find, and that many other similar ones would be discovered. This expectation, though natural, has not been borne out by events; for no important new districts of the same type have been discovered since, and the original camps after a history of less than twenty years find themselves already old and declining in real and comparative importance. Nevertheless, their development and exploitation have been exceedingly interesting episodes in the history of gold mining and the men who took part have added much to the science of mining and metallurgy not only in gold in but other metals.

The parallellism between the two districts is, I believe, more apparent than real. About the only point in common is the occurrence of tellurides of gold, but even in that particular the similarity is not by any means complete. At Kalgoorlie only a part of the gold is associated with tellurium, while at Cripple Crreek it nearly all is. The result is that in the two camps the metallurgical problem is different; at least it has been worked out differently.

When we come to geological and structural relations there is little similarity. At Kalgoorlie the veins are in a volcanic formation, apparently of great geological age, that has been subjected to severe and deep-seated dynamic action, resulting in the formation of strong lodes in shear zones.

Cripple Creek Mines

Cripple Creek, on the other hand, presents deposits in an extinct but geologically recent volcano. The rocks have not been subject to dynamic or metamorphic action, except those incident to the formation of the veins. The productive area is elliptical in outline with a length of about five miles from N.W. to S.E. and a width of three miles from N.E. to S.W., and contains numerous veins throughout, but the most valuable ones seem to be near the periphery of the volcanic mass, many being in the enclosing granites at or near the contact.

The veins are apparently all of the same age and of the same character, being deposits in fissures that result from adjustments following the cooling of the volcano. There was very little faulting along the veins either preceding or following the mineralization. The deposits vary in character according to the intensity of the mineralization along the fissures and according to the character of the rocks traversed by the fissures. In some cases a vein will be merely the quartz filling of an open crevice with very little impregnation of the wall rocks. In other cases, the deposit of quartz in the fracture planes is minute in quantity, but extends out into innumerable joint planes along which there has been a limited impregnation of the wall rocks. In this case the workable ores have the form of a stock-work. In still other cases the walls of a fissure are altered considerably for several feet on each side of the crevice by the introduction of new quartz replacing certain minerals in the original rocks. This occurs more commonly in the granite, but sometimes in basalt dikes, and wherever it happens the ore becomes a homogeneous mass.

Speaking generally, the ore deposits are either too small or too imperfectly mineralized to allow of the mining of merchantable ore in mass. A large amount of waste must be broken, of such character that it can better be rejected by hand sorting than by any other means. While it is not possible to give exact figures on this point it is a fair estimate that only 40 per cent. of the material stoped is shipped to the mills. The amount of development work required is very great. Up to 1903 it appears that some 2,300,000 ft. of shafts, drifts, crosscuts, raises, and winzes had been dug for a total output of some 3½ million tons of shipping ore and some 9 million tons of ore stoped.

Since the development work may be estimated to average some $14 a foot, it appears that it must have cost at least $8 a ton for all ore shipped from the district up to that time, for development alone. The cost of stoping the same ores must have averaged not less than $8 a ton more. The cost of freight and treatment in mills and smelters may be estimated at an additional $9 or $10, so that the total cost, exclusive of plant, was $26 per ton shipped and certainly more than $10 per ton stoped.

If we add the plants, the total estimate for all ores will not fall far short of \$30 per ton shipped, and \$12 per ton stoped. The ores averaged probably \$36 a ton, leaving a profit of about \$6 a ton or less than 18 per cent. of the gross value. These figures being for the district as a

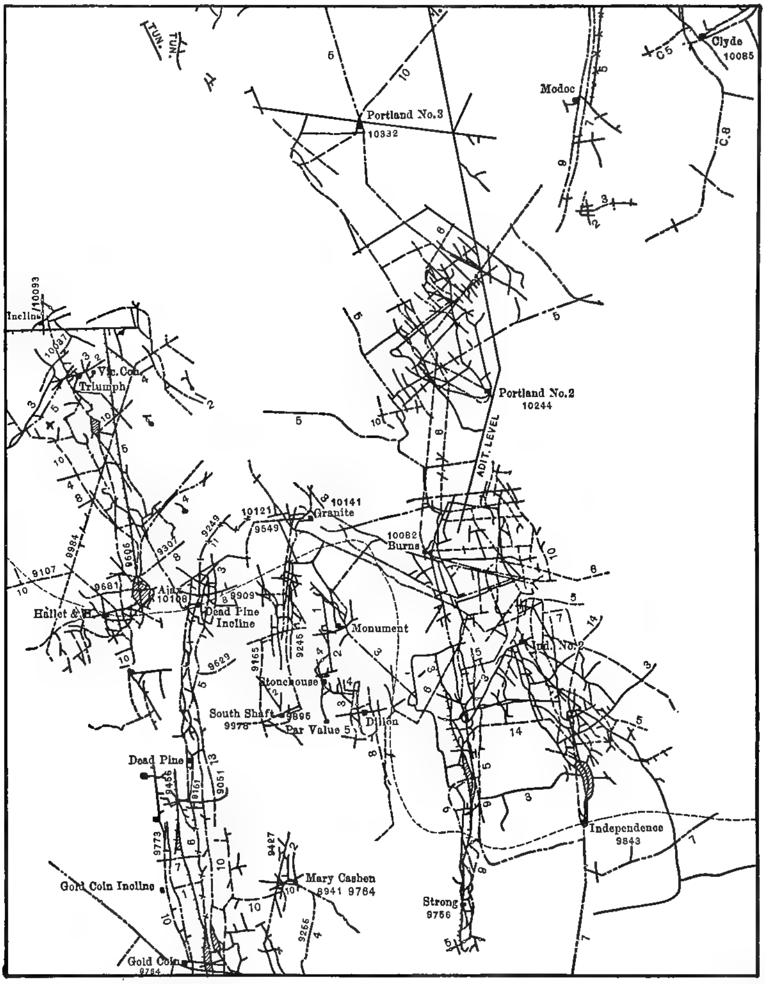

FIG. 11.—Illustration of the development work in the Portland mine and vicinity, where 1 foot of opening work has been necessary for mining 4½ tons of shipping ore.

whole, they naturally include a good many failures. Some of the mines have secured lower costs throughout their history, and many are securing much lower costs now. The dominant factor, however, in lower costs is the lowering grade of the ore. In 1899 the ore shipped averaged \$36.73 per ton. In 1906 the average had fallen to \$20.35 per ton.

Portland Mine

This is the best mine in the district and it presents good examples of all the types of deposit known in Cripple Creek. Most of the ore has come from an area of some 60 acres in which there have been done up to the end of 1908 above the 1500 ft. level no less than 212,593 ft. of development work. This development was necessary to open up a great number of veins, some of which were independent and others had a mineralized connection with other veins. The total production of shipped ore was 949,382 tons, valued at $29,430,842, giving an average of $31 per ton. The total amount stoped may be estimated at 2,400,000 tons, so that we may estimate that it required one foot of development work for every 4½ tons shipped and for every 11 tons stoped.

The dividends paid up to 1908 amounted to $8,227,800[1] and the quick assets to approximately $500,000 more, making total earnings $8,727,000, equal to $9.30 per ton shipped. A rough estimate of average costs is as follows:

	Per ton, shipped	Per ton, crude
Development	$3.00	$1.20
Plant	1.50	0.60
Stoping	8.00	3.20
Freight, treatment, and deductions	9.20	3.68
Total	$21.70	8.68

The recent history of the mine shows much lower costs largely due to a diminution of the grade of the ore and of the amount of development work done, and also to the fact that the company has been milling its own ores. In 1903 the mine was shipping ores at averaging $30 per ton and doing one foot of development work for 4½ tons shipped. In 1908 the grade of the ore had fallen to $19.45 per ton shipped and the development work was only one foot to 16 tons shipped.

The last report that gives operating costs in detail is that for 1905, from which I get the following data:

The costs were as follows:

Tons shipped	109,232
Average yield per ton after deducting mill losses	21.96
Development work accomplished	21,073 feet, equal to one foot to 5¼ tons.

Grouping the costs per ton shipped it appears that the expenses at the mine were $9.36 and those at the mill, including transporation, $5.94. The extraction of the mill was 95.82 per cent.

[1] In the ten years since this date the mine has paid only about $2,000,000.

	Per ton, shipped	Per ton, stoped estimated at 2½ times amount shipped
Stoping	$7.85	$3.14
Construction at mine	0.29	0.12
Development	1.22	0.49
Transportation to mill	1.37	0.55
Milling and construction	3.49	1.40
Amortization of mill	1.00	0.40
General expense	0.08	0.03
Total cost	$15.30	$6.12
Profit per ton	6.66	2.26

When we consider that the ore thus treated is obtained by rejecting at the mine a large part of the ore stoped, and that the rejection means a loss of some low-grade ore which must be computed to average some $2.50 per ton, we find that the losses from sorting, assuming that 60 per cent. is rejected, must equal $1.50 per ton stoped. On this basis it appears that the grade of ore that can be mined under the conditions exhibited is approximately $8 per ton where sorting can be practised, and where the ore can be shipped without sorting it must be $10 per ton.

With the still lower grade ores which have been mined since 1905 a certain lessening of cost is obtained by diminishing the proportion of development work and on account of the lower transportation cost for lower grade ores. The freights from the mine to the mill are based on a sliding scale according to the grade of the ore.

Milling[1]

The mill in which the ores were treated was built in 1901 at Colorado Springs, some forty-five miles from the mine. The cost of the milling plant is given at $910,000. Owing to the steady diminution both in volume and in grade of the ore it does not seem unfair to expect the practical exhaustion of the mine within a few years. The amount of ore treated in the past by the mill is approximately 600,000 tons and it does not seem unreasonable to charge the ore with $1 per ton for the amortization of capital in the mill. It must be remembered that this capital was obtained by withholding dividends from the stockholders, and the ore now being treated is enjoying the value thus created.

The mill treatment consists of dry crushing, followed by careful roasting of all the pulp; chlorination in barrels and concentration of the

[1] This mill was recently abandoned in favor of the improved cyanide process at the Golden Cycle mill.

tailings. The concentrates shipped amount, I believe, to about 1 per cent. of the ore.

The Portland mine while representative in a way of the whole Cripple Creek district is decidedly a better mine than most of the others. Its costs are undoubtedly below the average, although there may be some like the Strong and the Golden Cycle, which have enjoyed lower mining costs on account of having a more homogeneous ore. Its history is fairly indicative of the district in which variation in costs is probably due in the main to development work. Many properties that have produced just as good ore on the average as the Portland have not been profitable because their output has been spasmodic and the earnings from an occasional bonanza have been absorbed in propecting.

The Portland mine has been well and energetically managed from its very beginning. It has created its plant out of earnings and has consistently made money for its stockholders. From time to time there has been criticism of its management and methods, but I am convinced that such criticism has on the whole been ill-considered, being based largely on comparison with other properties that have issued only partial statements of costs for limited periods.

Cripple Creek is a good example of a mining camp where results have not been fully understood. For instance, it is, or was, commonly believed that labor in Cripple Creek was exorbitantly paid and ineffective. In my opinion the truth is the exact contrary of this. The miners of Cripple Creek have always been an exceedingly intelligent and effective lot of men. The wages average, it is true, some $3.40 for the eight-hour shift, but competition for the places has allowed operators to work with selected men. While the climate is fairly healthful the altitude of 10,000 ft. above the sea certainly diminishes one's endurance as compared with sea level conditions; but to clinch the argument as to comparative effici-

896 Ft. Drifts Averaging 5 Ft. by 7 Ft.

	Labor Costs	Per Foot
Tramming	$898.38	$1.00
Pipe and trackmen	125.12	0.14
Machine men	1,686.00	1.88
Total labor	$2,709.50	$3.02
Other Costs:		
Use of machines, air, etc	$867.57	$0.97
Repair A, cars, etc	69.98	0.08
Explosives	1,279.76	1.43
Hoisting	414.53	0.46
General expense, surveying, assaying, bosses	515.20	0.58
Grand total	$5,556.54	$6.20

1229 FT. CROSSCUTS 5 FT. BY 7 FT.

Tramming	$1,138.87	$0.93
Pipe and trackmen	149.37	0.12
Machine men	2,473.49	2.02
Total labor	$3,761.73	$3.07
Other Costs:		
Use of machines, air, etc	$1,191.24	$0.97
Repairs, cars, etc	111.28	0.08
Explosives	2,044.65	1.66
Hoisting	656.67	0.53
General expense, surveying, assaying, bosses	819.26	0.67
Grand total	$8,684.83	$7.07

112 FT. RAISES AND WINZES

Tramming	$105.76	$0.094
Pipe and truckmen	3.37	0.03
Timbermen	133.17	1.19
Machinemen	354.50	3.17
Total labor	596.80	$5.33
Other Costs:		
Use of machines, air, etc	$186.25	$1.66
Repairs, cars, etc	6.84	0.06
Explosives	158.52	1.41
Lumber and timber	170.65	1.51
Hoisting	44.41	0.40
General, bosses, assaying, etc	50.37	0.45
Grand total	$1,213.84	$10.84

ency of the highly paid labor of Cripple Creek with that of other places I will give the preceding figures on the cost of development work in the Portland mine for the first half of 1903.

The grand total cost for all underground labor was $7.068 for 2237 ft. of development work, equal to $3.11 per ft. While it is not possible to pretend that these figures are an average for the history of the mine, it is evident that they exhibit a good record of labor efficiency. The rocks through which these openings were made might be classed as eruptive rocks of average hardness, being andesites and granites. There was no pumping charged against these costs.

This is another evidence of the lack of correspondence in mining costs between rate of wages and the cost of labor. If the same kind of work is done cheaper anywhere I have not been able to find the place.

1919 Note.—Under present conditions it is hard to see how any of the Cripple Creek mines can pay.

Kalgoorlie Mines

As remarked above, the resemblance of Kalgoorlie to Cripple Creek is more apparent than real, being based largely on the occurrence of telluride ores in both places.

The external factors at Kalgoorlie are much less favorable on account of a dry hot climate and long distances from populous centers. The internal factors are more favorable than those of Cripple Creek.

The lodes in Kalgoorlie are much larger, more persistent, and better mineralized. Instead of being split up into a multitude of small veins containing short and inconstant ore shoots, Kalgoorlie mines have only a few lodes which present ore shoots of an average stoping width of 11½ ft. The lodes have been found to be payable to a depth of 2600 ft. Comparing the two districts at large, it is probable that Kalgoorlie has one capital advantage in having a much smaller proportion of development work to do. Recollecting that all Cripple Creek mines seem to require one foot of development work for every four tons stoped, making a cost of more than $3 per ton for that account alone, it seems that Kalgoorlie enjoys a considerable advantage in that particular. I have, however, no means of obtaining full figures for the whole district of Kalgoorlie, upon which to base an exact comparison, but am compelled to draw conclusions from the records of some individual mines as compared with the Portland mine.

In stoping the Kalgoorlie mines have a marked advantage in being able to avoid sorting. The ore is sent to the mills practically as it is broken in stopes of considerable width. There is no evidence, however, that the cost per ton of rock handled is any lower in Kalgoorlie than it is in Cripple Creek.

When we come to milling we find that the figures are somewhat in favor of the Australian district. The ores are milled on the spot, thus avoiding railroad transportation charges. The processes themselves are slightly cheaper than those employed at Cripple Creek, but the extraction of the gold is somewhat less perfect, being from 85 per cent. to 93 per cent. as against about 96 per cent. in the Colorado camp.

Two distinct methods are employed about equally. The first method is wet crushing in stamp mills followed by amalgamation, by concentration and cyaniding of sands and slimes, the concentrates alone being roasted and then treated by a special cyanide process. This process effects a saving of from 85 to 93 per cent. of gold at a cost of from $2.21 to $3.92 per ton, varying according to the size of the mills and the grade of ore.

The alternative process consists of dry crushing in ball mills followed by roasting the entire pulp and then cyaniding. This process saves from 90 per cent. to 92 per cent. of the gold at a cost which seems to average

somewhat higher than the other processes, averaging for two mines $4.20 per ton in 1905. The largest mills in Kalgoorlie have a capacity of more than 20,000 tons a month as against 10,000 tons for the Portland mill. It is possible that if Cripple Creek ores were milled on the same scale, the costs would be lower than they are. When we come to consider the difference in natural advantages between the two points, it is evident that the Kalgoorlie ores are at a disadvantage. They have to be treated under the most unfavorable conditions: water, coal, and all supplies being extremely expensive, while in Colorado the mills pay little or nothing for water and are situated in proximity to coal mines.

The following is given as a characteristic analysis of ore:

Silica	60 per cent.
Alumina	11 per cent.
Ferrous oxide	5½ per cent.
Pyrites	7 per cent.
Calcium carbonate	7½ per cent.
Magnesium carbonate	6 per cent.
Soda and potash	1½ per cent.
Water	1½ per cent.

The following table illustrates the diminishing grade of ore with increasing depth in the Great Boulder mine:

300–400	$29.60
400–500	39.90
500–600	49.50
600–700	18.80
700–800	28.70
800–900	27.20
900–1000	27.30
1000–1100	24.60
1100–1200	19.70
1200–1300	19.80
1300–1400	13.40
1400–1500	14.60
1500–1900	12.70

If we assume that this ore is worked with an extraction of 90 per cent., the actual yield would be somewhat less than $20 per ton. These figures are quoted from an article by Mr. G. W. Williams on "Mining Practice in Kalgoorlie," in the *Engineering and Mining Journal* of January 25, 1908.

Our English friends have been disposed to believe that their practice in Kalgoorlie has been superior to that of Colorado. It is possible that they may be right in this contention, but it must be remembered that they do not secure as high an extraction as the Colorado mills, and in making comparisons of costs they may overlook some of the dominant factors. In order to convey in general terms a comparison of the operations in the two camps I present the following tables showing the results

in 1905 at five of the principal properties of Kalgoorlie, trying in each case to present the figures as nearly as possible in the same manner as those given for Cripple Creek, and reducing all statements to short tons and American currency.

Note in 1919.—The output of this district has declined enormously.

KALGOORLIE MINES—WHERE ORES ARE CRUSHED WET IN STAMP MILLS AND ONLY CONCENTRATES ROASTED. RECORD FOR 1905—SHORT TONS

	Ivanhoe	Oroya-Brownhill	Golden Horse-shoe
Tons	196,569	112,713	249,800
Assay value per ton	$15.50	$30.21	$14.87
Loss in milling	2.36	2.11	1.65
Yield	13.14	28.10	13.22
Feet development for year	6,808	12,285	8.047
Cost development per ton	$0.82	$1.43	$0.49
Current construction	0.65	2.17	1.08
Working Costs:			
Breaking ore	1.50	0.83	....
Filling stopes	0.24	0.28	....
Tramming and hoisting	0.40	0.58	....
Total mining	2.12	1.69	2.24
Rock breaking	0.09	0.16	
Ore transport	0.03	0.12	
Milling	0.50	0.51	1.32
Concentrating	0.12	0.13	
Roasting concentrates ...... 1 ton con-	0.10	(1 in 16) 0.12	
Cyaniding concentrates ..... centrates	0.06	0.07	0.10
Fine grinding concentrates to 18 crude	0.02	0.09	
Fine grinding sands	0.16	0.31	
Cyanide by percolation	0.21		0.98
Cyanide by agitation	0.60	1.70	
Filter pressing	0.15	0.40	
Precipitation and smelting	0.11	0.11	0.13
Re-treating	0.01	0.22	....
Maintenance	....	....	0.06
Total treatment	2.21	3.92	2.59
General expense London and Kalgoorlie	0.51	0.64	0.42
Realization of bullion	0.14	0.25	0.02
Deduct profit on stores	0.10	0.14	....
Net working costs	4.94	6.36	....
Taxes	0.30	0.80	0.31
Freight and treatment on ore shipped (Golden Horseshoe = $22.79 per ton)	....	....	2.11
Total estimate of cost	6.45	10.76	9.26
Losses in milling	2.36	2.11	1.65
Total costs and losses	8.81	12.97	10.91
Profit per ton	6.69	17.24	3.96
Percentage profit	43	57	27

Kalgoorlie Mines where all Ores are Roasted

	Great Boulder Proprietary	Great Boulder Perseverance
Tons	147,900	165,465
Assay value	$20.56	13.94
Loss in milling	2.47	1.30
Yield	18.09	12.64
Development feet incl. diamond drilling	7,373	14,163
Costs per ton treated	....	....
Plant expense	1.41	0.51
Development	1.07 (average 3 yrs.)	1.60
Mining—Ore breaking	2.07	2.20
Treatment—Sulphides	2.13	3.81
Cyanide plant (tailings)	1.01	0.95
Tailings distribution	....	0.12
Tailings transport	....	0.35
Realization of bullion	0.05	0.16
Purchase tailings	....	0.04
Insurance	....	0.10
General expense—London	0.31	0.24
Kalgoorlie	0 39	0.29
Taxes Australia	0.49	0.11
Grand total cost per short ton	8.93	10.48
Mill losses	2.47	1.30
	$11.40	$11.78
Profit per ton	9.16	2.16
Percentage profit	44.5	15.5

Casting up an average of the ore produced by these mines we find that the assay value of all five was about $17.60 per ton. It may be interesting to make a sort of comparison between these mines and the Portland of Cripple Creek in order to observe the difference in results obtained on an ore of equivalent value in the two districts. In order to avoid the labor of averaging costs let us take the results of the Ivanhoe mine, which produces ores nearest the average in grade, and assume that the Portland mine were producing the same grade of ore, using the costs reported by each for the year 1905.

Comparison of results at Ivanhoe and Portland mines, assuming that each produces ore averaging by assay $15.50 per ton, but that the Portland mine rejects by sorting 60 per cent. of ore stoped and that the waste rejected averages $2.50 per ton: (Table follows.)

The Ivanhoe is stated by Mr. J. H. Curle ("Gold Mines of the World") to be the best managed mine in Kalgoorlie. Furthermore, it is one in which the wet crushing method is used. Undeniably it is

Ivanhoe		Portland	
Tons mined per foot development..	27	Tons mined per foot development.	13
Cost development...............	$0.82	Cost development...............	$0.49
Cost for current construction mine and mill.....................	0.65	Current construction mine only...	0.12
Mining.........................	2.12	Mining and sorting..............	3.14
Sorting losses..................	0.00	Sorting loss 60 per cent. of $2.50..	1.50
Transportation to mill...........	0.03	40 per cent. of $2.00.............	0.80
Milling.........................	2.18	40 per cent. of $3.50.............	1.40
Amortization of mill (included under construction)	0.00	40 per cent. of $1.00.............	0.40
General expenses................	0.85	(included in costs mainly)........	0.03
Loss in milling..................	2.36	4 per cent. of $35.00.............	1.40
Total costs and losses...........	9.01	....	9.28
Deduct profit on stores..........	0.10	....	0.00
Net cost.......................	8.91	....	9.28
Profit per ton..................	6.69	....	6.22
Percentage profit...............	43	....	40

the one with which the Portland can least afford to compare itself. Were we to take the Great Boulder and the Perseverance for comparison we should find the figures very much in favor of the Colorado property. Those properties show milling costs of $3.19 and $5.39 respectively, and exhibit the following comparison (using the same figures for the Portland as before).

	Great Boulder Proprietary	Great Boulder Perseverance	Portland
Assay value of ore........................	$20.56	$13.94	$15.50
Total operating costs......................	8.93	10.48	6.38
Loss in milling and sorting.................	2.47	1.30	2.90
Total costs and losses....................	11.40	$11.78	$9.28

It is plain that there is no ground for making a comparison favorable to one district and unfavorable to the other; and that if the managements in the two districts were to be exchanged the stockholders would not have much cause to worry.

Since 1905 the mines have undoubtedly succeeded in lowering their costs somewhat, as in the case of Cripple Creek, in proportion to the diminishing grade of the ore. The Golden Horseshoe mine in the years 1907 and 1908 treated 554,131 tons with an average yield of $10.95. The dividends paid were $2,405,600, equal to $4.34. Assuming that the

dividends equaled the actual profit, the cost figures out at $6.61 per ton. This compares with the total of $7.15 for the same mine in 1905. It is to be remarked that in the tables given above the Golden Horseshoe ships 7 per cent. of its ore to smelters in the form of concentrates and high-grade ore. This imposed a further cost of $2.11. This mine is still securing a profit of 40 per cent. of the gross value of gold produced. Its complete record for eleven years' operation shows an output of $33,-154,000 in gold, from which $13,468,000 have been paid in dividends, equal to 41 per cent. of the gross yield. The total number of tons treated is not given, but it will approximate two million, so that the yield for the life of the mine has been about $16.70 per ton and profits $6.70, leaving $10 as the cost of operating, including all plant and development. The records of the mine, however, do not indicate the expenses and deductions incurred for shipping ore to the smelters, simply reporting the sums received net from such shipments. If these expenses were included it is probable that they would make an addition of something more than $2 per ton to the costs and to the yield of gold, making the total costs something more than $12, and the yield of gold approximately $19 per ton. If the extraction averaged 90 per cent., the gross assay value of the ores mined would be about $21, which approximates very closely to that of the Great Boulder.

No mines in Cripple Creek have produced anything like such quantities of ore of this grade, nor have they earned such large dividends. The fact is that the Kalgoorlie camp contains only nine or ten mines of first-class importance, but these have produced nearly all the gold and all of the dividends of the district. In them the values have been concentrated into a much smaller space than in the case of Cripple Creek, where the output has come from a large number of comparatively small producers, and where payable values have practically ceased at a depth of 1200 ft. This group of dividend-paying properties are therefore better and higher grade mines than any in Cripple Creek. Their outlook for the future is also far more attractive. The Ivanhoe reports reserves of 934,000 tons, averaging $11.75 per ton, and good ore at the 1970 ft. level; the Golden Horseshoe 1,065,000 tons averaging $12, with $15 ore on the 2000 ft. level; the Great Boulder 731,000 tons, averaging $16, and good ore on the 2600 ft. level; the Associated 483,517 tons, averaging $10 per ton; in each case assuring the product for 3 to 4 years, and an average profit of 40 per cent. of the gross value. It would not be surprising if they proved payable to much greater depths.

Goldfield, Nevada

This district was discovered in 1903 about twenty miles south of the somewhat older camp of Tonapah, the success of which had served to attract many prospectors to the comparatively old mining regions of

Nevada. The discovery in that year of some rich ore on the Jumbo and Combination mines started a considerable excitement during 1904 followed by comparative quiescence during the latter part of 1905; but the discovery of an extraordinary bonanza on the Mohawk claim in April, 1906, encouraged the recrudescence of the mining boom not only in Goldfield but in other parts of Nevada, until the excitement reached by the end of 1906 a degree of extravagance for which it would be hard to find a parallel. About that time the owners of the Mohawk, pursuing their good fortune with commendable intelligence and energy, secured most of the promising ground in the camp and formed the Goldfield Consolidated Mines Company, which is to-day, after a period of reorganization and development, the most productive and profitable gold mine in the world.

The Goldfield district is in a region of volcanic rocks of doubtful but probably rather recent geological age. A series of great quartz veins, or rather zones of silification is found, indicated by a series of bold outcrops which have a strike usually nearly north and south. It seems probable that the gold belongs to a later mineralization, because the quartz masses are nearly or quite barren. The rich ore shoots seem confined to smaller fissures that traverse the great quartz masses in various directions and have produced a considerable amount of brecciation in them. These later fissures often cut the great quartz reefs at right angles and the ore shoots seem rather more apt to occur along the flanks than in the interior of the reefs. There have been discovered a number of rich bonanzas, probably due in considerable measure to a process of reconcentration near the surface, but exploration has not proceeded deep enough to establish this as more than a probability.

The grade of the ore is already diminishing rapidly owing to causes that are universal in such districts. Owing to lack of treatment facilities on the ground, and to the high cost of transportation, at the beginning, only high-grade ores could be shipped. In 1906 the Mohawk bonanza produced in eight months upwards of 70,000 tons of ore averaging $120 per ton. With the institution of milling plants on a large scale, lower grade ores can be treated so that at present the Goldfield Consolidated is mining 20,000 tons a month of ore averaging $40 a ton. That such values will be maintained is an unreasonable expectation that has never been indulged in by the management. I am led to believe that the actual developments indicate about one-half a million tons of ore that will average between $20 and $25.

During 1907 and 1908 the efforts of the management have been directed towards the completion of a satisfactory organization, the prosecution of development and the construction of a new mill. This was done so successfully that at the beginning of 1909 the property was ready to begin extensive operations on a new basis. A magnificent modern mill

was built with a capacity of 600 tons a day with a railroad to provide for transportations of ores to it, together with some additions to the mining plant at a total expense of $900,000.

During 1908 17,460 ft. of development work was done by the company at an average cost of $17.60 a foot and 20,463 ft. were done by leasers. The amount of ore developed by this work is not stated, but the lessees shipped only 25,600 tons and probably did not put much ore in sight, so that this portion of the development work only seems to have opened up to 1¼ tons per foot. What the cost for development will average is a question that probably will only be determined after several years' experience, but judging from the large amounts done to date, it is hardly likely that the cost per ton will be less than $2 from this item.

The cost of stoping will undoubtedly vary according to the extent to which ore must be sought in narrow seams, but experience to date seems to indicate that ore of the milling grade will be found in fairly wide stopes, so that the cost of stoping will probably be about $2. In addition to this the report for 1908 seems to indicate that general expenses will approximate 30 cents per ton on an output of 240,000 tons a year. It would seem therefore, that the cost of mining might be calculated at about $4.30.

Milling

Mr. J. H. MacKenzie, manager, describes the milling process briefly as follows:

> "Crushing in gyratory rock breakers and stamps, with regrinding to slime and tube mills; amalgamation over copper plates both before and after milling; concentration by means of Deister slime tables; cyanidation of tailings from concentrators with the aid of Pachuca agitators and Butters filters and zinc dust precipitation. Concentrates are treated in an auxiliary plant by means of a modification of the cyaniding process, and products from all departments of the mill are refined and shipped directly to the mint as gold bullion."

This process is very similar to that employed at Kalgoorlie and it is very probable that the costs will be approximately the same. Experience in actual operation has not gone far enough to demonstrate exactly what it will be, but it is worth remarking that the mill is an extremely good one and works with the greatest precision, giving an extraction of about 94 per cent. gold. If we assume that the costs will be the same as at the Ivanhoe in Kalgoorlie, which is a modern mill of the same size, namely, 100 stamps, we may calculate the cost of treatment at $2.20 a ton including transportation from the mines.

It is to be remembered that the cost of the plant is approximately $900,000. Owing to the erratic character of the ore it would seem wise to amortize the plants in five years, which would make a calculation for 75 cents a ton. We may also calculate that current construction will

amount to about 25 cents a ton, making a total plant cost of $1 per ton treated. On this basis we might calculate the costs as follows:

Mining	$4.30
Milling	2.20
Construction	0.25
Total current costs	$6.75
Add for amortization	0.75
Total cost per ton	$7.50

With an extraction of 94 per cent. these costs indicate that the minimum assay value of a payable ore should be $8 a ton.

While the above figures are given only as approximations it is nevertheless true that they are made with some reference to the figures unofficially given out by the company for the present year and they may be accepted with some confidence.

For the present year the yield of gold from this property promises to be enormous, perhaps $8,000,000 gross, on which net profits upwards of $5,000,000 may be realized. Such an output will be a new record among the gold mines of the world.

Note in 1919.—All these hopes were more than realized for a few years. In 1910 and 1911 more than $14,000,000 was paid in dividends, but by 1915 the mine had become practically unprofitable and is now shut down. For details of cost see Peele's Handbook.

CHAPTER XXIX

SILVER MINING AT COBALT AND GUANAJUATO

PHENOMENON OF THE SUDDEN DECLINE OF THE PRICE OF SILVER COMPARED WITH GOLD —PRESENT INFERIOR POSITION OF SILVER MINING—COBALT AS AN EXAMPLE OF HIGH MINING COSTS—LOGIC OF COSTS—KERR LAKE—TINTIC—CHIEF CONSOLIDATED—GUANAJUATO—TOMBSTONE.

SILVER MINING

BY far the greater portion of the silver of the world is now obtained as a by-product from mines that are operated chiefly for lead, copper, or gold; and in this connection the metal has been frequently touched upon in preceding chapters. There are only a few conspicuous districts now where silver is the primary object of the mining industry. Some

FIG. 12.—The drop in value of silver.

remarks on two of these, Cobalt, Ontario, and Guanajuato, Mexico, are sufficiently interesting to warrant insertion.

The present obscure position of silver mining is due to one of the most remarkable economic revolutions in history. In the course of twenty-five years in the latter part of the nineteenth century silver declined in value from $1.30 to about 55 cents per ounce, and in so doing suddenly lost, apparently forever, a position of importance as the companion of gold that it had held in the estimation of mankind for thousands of years. It is no wonder that such a violent and unprecedented fall

astounded the generation that beheld it, and put in play that instinct which attributes any mysterious unpleasant happening to design, and which, in this instance, took the form among the half-informed of an accusation against financiers of a gigantic "conspiracy." It is infinitely more probable that the financiers of the world understood the reasons for the fall of siver as little as other people. It is no part of the present work to offer an explanation; merely to point it out as the most conspicuous example of a great commodity suddenly taking a price level radically different from its traditional one.

The comparatively unimportant position now held by silver mines would be very different had not the fall in prices taken place, for with silver at $1.29 an ounce, many of the important mining districts would be more valuable for their silver than for anything else. The Cœur d'Alenes, Park City, Tintic, and many other districts would be so changed in the relative importance of the metals they produce that they could safely be called silver-mining camps producing lead, gold, and copper as by-products.

Cobalt District, Ontario

Cobalt is unique not only on account of the geological occurrence of its ores, but also because it is an example of the absolute inconsequence of high costs per ton in precious metal mining. So far as I know the Cobalt ores are mined at the highest cost of any ores of importance in the world, yet their silver contents are secured at the lowest cost, with the largest margin of profit. The district belongs to the same series of pre-Cambrian rock formations that has proved so prolific in iron, copper, and nickel near the shores of Lake Superior; but at Cobalt the orebodies instead of having the grandiose character so universal in Lake Superior, are exceedingly small, disconnected, and rich. The geological resemblance to Lake Superior extends to the character of the surface, which is highly glaciated and covered with swamps and lakes with low rounded knobs of more resistant rocks forming occasional eminences above the generally level country. The rocks consist of the ancient greenstone schists, usually called the Keewatin, with some troughs of Huronian quartzites and conglomerates, the latter invaded by dykes, and sills of biabase. The veins occur in all of the rocks to some extent, but chiefly in the sedimentary formations.

The superficial extent of the district is several thousand acres, but the individual orebodies are so small that they might almost be described as minute. They are usually only from one inch to six inches wide and from a few feet to 150 ft. long, and ordinarily of no great depth. This at least applies to the ore shoots. Some veins that are barren on the surface contain ores at greater depth. While the absolute bottom of the district has not been reached, the hopes of the operators are more fixed

on discovering new veins than on following old ones in depth. The vein filling is largely calcite with some quartz. The ore consists largely of native silver, but associated with it are some of the richer sulphides, dyscrasite, argentite, pyrargyrite. With the silver occurs cobalt, nickel, and arsenic in smaltite, niccolite, and other minerals.

The problem of mining such ores consists largely in finding them. Once found the principal problem is to extract them cleanly—no concentrating process being so efficient for the purpose as hand sorting.

FIG. 13.

The ores once secured are shipped to the smelters at a cost for freight, treatment, and deductions of over $50 a ton.

But the ores thus mined contain 750 oz. of silver per ton, so that $50 for all treatment charges only means 7 cents an ounce. The cost of mining in the whole district, outside of treatment charges, seems to have averaged about $145 a ton, probably divided about equally between development and extraction. Even this high figure only means 20 cents an ounce.

It is almost amusing to speculate on the surprise that a Lake Superior

miner must feel at such tremendous costs per ton; nevertheless, there is not the slightest ground for supposing that these high costs do not represent just as good mining practice as any in Lake Superior. It is for the purpose of illustrating this fact that the mines at Cobalt are interesting in a work on the cost of mining.

Let us neglect the question of finding ores and assume that it costs \$75 a ton to get them out of the ground. What does this mean in comparison with the cost of say \$1 a ton for mining the ore at the Wolverine? Simply that it takes seventy-five times as much work to get it out. That this should be so is a direct result of the size and thickness of the ore bodies. In the case of the Wolverine the thickness is 15 ft. or 180 in. and the ore is placed on surface for \$1 per ton. It is probable that if the ore body were only 4 ft. thick and as continuous as it actually is, the mining cost at the Wolverine would be about \$2 a ton. Now since an opening 4 ft. wide is about the least that can be made, a cost greater than \$2 a ton will be simply an inverse ratio of the actual thickness to 4 ft. If the Cobalt ore is to cost \$75 per ton we might calculate the thickness of it at 48 in. $\div$ $^{75}\!/_{2}$ = 1.28 in.

A continuous seam, then, of ore 1.28 in. thick ought to cost \$75 a ton for mining. It means exactly the same thing if a series of bunches, averaged up, amount to a mean of 1.28 in.

In the light of the figures there is no mystery in the fact that an orebody 1.28 in. thick may be a bonanza. It is worth \$400 a ton. If this value were scattered through 4 ft. of a continuous orebody, it would give a value to the whole mass of \$11 a ton, equal at average prices to 75 lb. of copper, which every one would recognize as a bonanza. Such an orebody would give, under the costs prevailing among Lake Superior amygdaloid mines, figures something as follows:

Mining per ton	\$2.00
Surface expense, transportation, and milling	0.90
Construction and amortization	0.50
Smelting, refining, and marketing	0.80
Total	\$4.20

Cost per pound copper about 5.6 cents.
At fifteen-cent copper the profit would be 63 per cent. of the gross value.

If we scatter the values through a mass 15 ft. thick, there would be the equivalent of 20 lb. copper per ton, and the costs would be:

Mining	\$1.00
Surface, expense, transportation, and milling	0.65
Construction and amortization	0.30
Smelting, refining, and marketing	0.22
Total	\$2.17

Cost per pound copper, 11 cents.
Profit on gross value, 27 per cent.

In the case of the 4-ft. orebody the costs per ton would be approximately twice as high as in the case of the 15-ft. orebody containing the same copper, but the cost of copper would be only half as great and the profit more than twice as much.

This makes it plain enough that the concentration of values is a great economic advantage.

In the case of the Cobalt orebody 1.28 in. thick (always neglecting the question of prospecting), on the theory of a continuous seam, the results are as follows:

Mining per ton	$75.00
Smelting and marketing	50.00
Total cost per ton	$125.00

Value per ton, $400; profit, 69 per cent.

But in Cobalt there is no continuity. The ore must be looked for at an additional cost of $70 a ton so that the actual profit is reduced to 52 per cent. Nevertheless it is quite simple to show that a natural concentration in values involving enormous increases of cost per ton is a distinct economic advantage.

RECORD OF COBALT AS A WHOLE

	Tons	Ounces silver	Value	Dividends
1904–1908	48,545	35,083,300	$19,495,000	$10,000,000 ±

$$\text{Cost per ton} = \frac{9,495,000}{48,545} = \$195$$

Value per ounce, 55.7 cents
Cost per ounce, 27 cents

NIPISSING MINE

1904–1908	8,449	8,145,834	$4,540,000	$2,640,000

$$\text{Cost per ton} = \frac{\$1,300,000}{8449} = \$154 \pm$$

Cost per ounce, 16 cents ±

NIPISSING MINE, 1908

Tons shipped, 3505; ounces silver, 2,893,931; ounces per ton, 826

Costs	Dollars	Per ton	Per ounce, silver
Operation	$361,274.85	$105.46	$0.13011
Depreciation	44,631.66	13.03	0.01607
Marketing ore	174,775.66	51.02	0.06294
Legal, etc	22,292.51	6.50	0.00803
Less income	$27,761.61	$8.10	$0.01000
Total	$575,213.07	$167.91	$0.20715

There is good reason to believe that the above figures for 1908 are ample. They include a depreciation charge on plant and buildings of 24 per cent. It appears that the cost of "prospecting" "exploration," and "development" (whatever they may separately mean) amounts to some 37 per cent. of the total cost of "operation."

Kerr Lake Mining Company

For the year ending August 31, 1908, this company showed the following record:

Tons mined, 528; ounces silver, 1,473,712; ounces per ton, 2790.

Costs		Per ton	Per ounce
Production and development	$139,530	$264.25	$0.0947
Shipping and smelting	76,093	144.30	0.0516
General expense	32,904	62.30	0.0223
Plant and machinery	57,419	108.75	0.0390
Total	$305,946	$579.44	$0.2076

This is probably a new record for high costs per ton, yet silver was produced for less than 21 cents per ounce and the profit was nearly 70 per cent. of the gross value.

Not all of the Cobalt ores are of such high grade, several of the mines being now equipped with mills for concentrating, but the mills only handle a small tonnage and it is safe to say that if Cobalt had to depend on the low-grade ores it would never have been heard of.

The Kerr Lake in 1918 had the following record which illustrates I suppose the changes that have taken place in 10 years. About 2,583,000 ounces of silver were taken from 48,542 tons of rock hoisted.

The costs were	Per ton rock	Per ounce silver, cents
Mining	5.11	9.6
Treatment, etc	3.34	1.0
General	0.50	2.3
Outside explorations	1.24	2.3
Taxes	4.70	9.0
Total about	14.89	28.1

Mining Cost per Ton of Rock Hoisted—September 1, 1917, to August 31, 1918

Tons rock hoisted, 48,542	Ore 43,129 tons	Sacking ore, 1st Grade	400 tons
		No. 1 Ag. Co	610 tons
		No. 2 Ag. Co	7 tons
			1,017 tons
		Mill ore	27,835 tons
	Mine waste 5,413 tons		28,852 tons
		Waste from bumping table	14,277 tons
		Total	43,129 tons

The following were the costs:

48,542 tons rock hoisted at a mining cost of .... $5.11 per ton

2,582,992.82 ounces silver at a mining cost of .... 9.6 c. per ounce

Operating and Profit and Loss Account—For the Year Ended August 31st, 1918

Cost of production and development:			Proceeds of ore sales.......	$2,122,951.04	
Stoping................	$25,515.52				
Development...........	24,946.05				
Power, light and heat...	25,658.51		*Less*:		
Ore sorting and jigging ..	15,725.75		Ore on hand, at smelters, and in transit, August 31st, 1917 (estimated)......	335,141.04	
Tramming..............	29,152.96				
Hoisting................	7,023.18				
Timbering..............	22,224.75				
Pumping...............	2,809.55				
Mine expense...........	13,961.70				
Sampling and assaying..	5,062.82			$1,787,810.00	
Drills and steel..........	13,709.01				
Office expense...........	6,652.67		*Plus*:		
General expense.........	1,735.59		Ore on hand, at smelters, and in transit August 31st, 1918 (esmated)........	549,335.67	$2,337,145.67
Repairs to plant and buildings..............	3,259.64				
Surface maintenance.....	10,475.99				
Stable expense..........	6,150.17				
Boarding house expense..	1,698.15				
Insurance...............	2,361.44				
Timber berth............	2,090.90				
Taxes..................	27,632.72	$247,847.07	Interest......................		57,073.69
Shipment, treatment and other charges:					
Shipment expense.......	$4,228.32				
Milling.................	8,747.15				
Freight.................	14,043.52				
Ore treatment...........	110,017.85				
Assaying and sampling ..	4,941,89				
Insurance..............	19,950.30	161,929.03			
Administration and general expenses:					
Directors' fees..........	$620.00				
Donation to Red Cross...	5,000.00				
General expense.........	9,596.11				
Compensation of manager and engineers.........	8,899.99				
Travelling expense......	243.20	24,359.30			
Expenses in connection with lake draining and exploration of outside properties.............		60,270.42			
Estimated for taxes..................		227,496.90			
Balance, being profit transferred to balance sheet.........................		1,672,316.64			
		$2,394,219.36			$2,394,219.3

Tintic District

A conspicuous example of several important features of the mining industry is afforded by the Tintic district of Utah, situated about 90 miles south of Salt Lake City. Perhaps it should always have been described as a silver mining camp but during the low prices for that metal considerable attention was paid to the copper, lead and gold which the ores also contain.

A great series of quartzites, limestones and shales of Paleozoic age forms a mountain ridge known as the Oquirrh Range, the summits of which

rise to heights of about 8000 ft. Toward the east the ground slopes down regularly toward Utah Lake, which is the southward continuation of the Great Salt Lake valley and lies with an elevation of only 4400 ft. at the foot of the abrupt and imposing uplift of the Wahsatch; toward the west there is a desert valley the elevation of which is about 6000 above sea level. The crest of the range is a great syncline, the western side of which stands nearly verical; but the east side dips rather gently toward the west. This syncline is broken by two intrusive masses each of which occupies a roughly, quadrangular section across nearly the whole range. Of these the southerly one is a granitic batholith which contains within its body a number of productive fissure veins; the northerly one is a funnel shaped mass of rhyolite apparently spread out like a mushroom at the top. It is quite unmineralized. Between these two masses the great syncline of limestone contains numerous tortuous channels of ore which must have emanated at greater depth from the monzonite magma. There is nothing impossible in the supposition that the rhyolite also may be a superficial phase of an offshoot from the same magma. The monzonite mass has produced a good deal of contact metamorphism, turning a fringe of the limestones into marble, but the rhyolite has not affected them noticeably. The eruptive masses hold water at, or near, the surface; the intervening or underlying limestones were thoroughly drained by nature almost down to the level of Utah Lake, and the ores oxidized to that depth, that is to say, to an average of not less than 2000 feet below the surface.

Up to the end of 1917 this mass of limestone partially explored down to, say, 2000 ft., had produced ores containing a gross value of $170,000-000 from an area of 2200 acres. I suppose the tonnage shipped must have been about 7,000,000. The mass of limestone would weigh about 2200 times as much as the ore that has come from it. How much more it may contain is of course unknown, but there certainly would be nothing startling in supposing that such a proportion of ore might be increased. The output of the district shows little signs of falling off, if any, but the principal locus of extraction varies from time to time as discoveries are made. The profits of such mines as have paid at all have been a scant 20 per cent. of the gross value of the metals shipped by them.

Chief Consolidated

For some years this mine has been the largest producer of the district. It occupies a large part of the northern portion of the productive area. This land was, in the earlier life of the camp, thought to be entirely unmineralized because the surface is occupied by the barren rhyolite that was mentioned above. But below these volcanics the limestones are mineralized to an unknown distance northward, Acting on this knowledge the company has acquired lands in that direction until it has

expanded its holdings from about 100 acres in 1909 to about 5000 acres at present. The output in eight years up to the end of 1917 was 323,803 tons with a gross value at average prices of about $7,500,000 as follows:

Gold 0.13 oz. at $20.67	$2.68
Silver 22.4 oz. at 0.60	13.44
Lead 151 pounds at 0.045 cents	6.75
Copper 1.1 pounds at 0.15 cents	0.16
Zinc 7.0 pounds at 0.55 cents	0.38
Total	$23.41
Less smelter costs and deductions about	11.41
Average net value at the mine	12.00
Cost of equipment mining and development	6.60
Mining profit	$5.40

But a policy of constantly buying more property in order to provide opportunity to open up ore has cost something like $1.00 a ton additional, even estimating that the ground thus secured will eventually yield several times the tonnage already produced; so that the actual net profits can hardly average more than about $4.40.

These were oxidized ores, occurring in long tortuous channels through the limestone. The mineralization consists principally of quartz, with lead, silver etc., scattered irregularly through it.

But on reaching the water level at about 1800 feet depth a different grade of ore was encountered. This is shown by the report for 1918. The ore is now a sulphide, presumably somewhat enriched in silver.

Gold 0.68 oz. at $20.67	$1.40
Silver 39.7 oz. at 0.986	39.15
Lead 111 pounds at 0.07	7.77
Total	$48.32
Smelter deductions	14.82
Net to mine	33.50
Cost of mining, development and equipment	17.17
Mining profit	16.33

It will be observed that the costs are enormously higher than before. This is explained by the fact that when earnings are large a proportionately larger sum is spent on development and improvements. Besides this additional cost is incurred in pumping. But of course the main cause of the rise was the general war inflation. In this mine it has required on the average 1 foot of development work for 4 tons extracted.

Guanajuato, Mexico, 1908

Guanajuato has the reputation of having been the most productive silver-mining district in the world; its total output exceeding one thousand million ounces. It is the very reverse of the Cobalt district in

geological structure, ore deposits, and methods. The rocks, instead of belonging to the ancient Algonkian series, belong to the comparatively recent Cretaceous. Instead of the multitude of small veins there are four or five very large fault fissures carrying a strong mineralization of quartz and silver sulphides. The mining methods, instead of depending on the careful sorting of small streaks of rich smelting ore, are designed to extract large quantities, and finally, the treatment, instead of being smelting as at Cobalt, is confined almost entirely to cyaniding. In the early days (and by early days I mean the period of more than two hundred and fifty years following 1550, during which an occasional bonanza was discovered) it is probable that Guanajuato bore a much closer resemblance to Cobalt than it does to-day. It is likely that a very large amount of high-grade ore was then mined and that the lower-grade ores of the present day have become valuable more because the rich ores of former times are no longer to be had than for any other reason. In other words it is probable that if the high-grade ores of former times were now available the ores being mined at present would not excite much attention. It has often been remarked that Guanajuato bears a close resemblance to the Comstock lode in Nevada, and its history has been similar; but its life has been longer and its output greater. The longer life of the Mexican camp has been chiefly due to the fact that until recently it has not been worked with American appliances and energy, the result being that at Guanajuato, after a life of three hundred and fifty years, the deepest mines have reached a depth of only 2000 ft., while on the Comstock lode explorations reached a depth of over 3000 ft. within thirty years after the first discovery.

The present mining activity of Guanajuato is chiefly in the hands of Americans and is extremely recent, dating back only to 1904 when it was first satisfactorily demonstrated that the ores could be economically worked by the cyanide process. Since that time the output of the camp has increased very rapidly. It has now reached an annual output of about ten million ounces, divided among some eight or ten producing mines. The average ore is probably worth some $7 or $8 per ton, the values consisting of about 13 oz. of silver and 0.05 oz. of an ounce of gold.

The economics of the districts are somewhat as follows: Labor is very cheap and just as poor as it is cheap; miners earning from $1 a day down. There is no evidence here any more than in India or South Africa that low wages means cheap operating. Water-generated electric power has been brought into the district by American enterprise from a distance of some 110 miles. This power was first used by the mines in 1905 and its introduction proved a great advantage and has much to do with the success of the mining enterprises. Electric power is sold at $75 per horse-power per year, which is a very moderate price; before its introduction steam power cost some $200 a year.

COST OF CYANIDING, GUANAJUATO DEVELOPMENT COMPANY'S MILLS

Mill	Period 1908	Wet tons milled per month	Crushing			Con-centra-tion	Classi-fying	Treatment		Filtering and precipi-tation	Pump-ing solution	Water supply	Surface expense	All costs				
			Coarse	Fine	Re-grind			Sand	Slime					Labor and bosses	Sup-plies	Power	Miscel-laneous	Grand total
Peregrina	Average of 4 months	12,356	$0.079	$0.395	$0.185	$0.061	$0.011	$0.346	$0.253	$0.189[1]	$0.067	$0.022	$0.020	$0.453	$0.748	$0.415	$0.003	$1.619
	Minimum monthly tonnage	11,324												0.485	0.910	0.425	0.005	1.825
	Maximum monthly tonnage	13,593												0.440	0.665	0.380	....	1.485
Pinguico	Average of 8 months	6,188	$0.075	$0.305	$0.235	$0.080	$0.020	$0.460	$0.405	$0.415	$0.050	$0.080	$0.040	$0.720	$1.090	$0.355	....	$2.165
	Minimum monthly tonnage	5,820												0.825	1.140	0.365	....	2.330
	Maximum monthly tonnage	6,168												0.675	0.975	0.325	....	1.975
San Próspero	Average of 7 months	4,014	$0.055	$0.340	$0.100	$0.050	$0.025	$0.390	$0.360	$0.310	$0.065	$0.040	$0.015	$0.470	$0.875	$0.395	$0.010	$1.750
	Minimum monthly tonnage	5,820												0.510	1.100	0.470	....	2.080
	Maximum monthly tonnage	6,168												0.465	0.860	0.335	....	1.660
Nayal	Average of 6 months	1,347	$0.115	$0.600	......	$0.135	$0.205	$0.595	$0.430	$0.290[1]	$0.045	$0.035	$0.045	$1.020	$1.045	$0.420	$0.010	$2.495
	Minimum monthly tonnage	1,168												1.065	1.350	0.535	....	2.950
	Maximum monthly tonnage	1,477												0.950	0.915	0.285	....	2.150

[1] No filtering plant at this mill.

A number of good mills have been built and are now operating in the district, the results of which are given in an accompanying table. It will be seen that the operating costs vary from $1.62 per ton for a mill of the capacity of 400 tons a day to $2.50 a ton for one having a capacity of only 50 tons.

I have found the plant expenditures stated for only one mine—the Pinguico—at which the total cost for plant and equipment, including mill, mill site, storehouse, supplies, etc., was $680,000, providing for a treatment capacity of some 80,000 tons a year. If this mine may be taken as an average for the district, we may calculate that the plant costs somewhere around $8.50 per ton of annual output. Since there is every reason to believe that these mines will be fairly long-lived, it seems rational to amortize the capital over a period of fifteen years so that in round numbers the capital employed is worth 10 per cent., or $0.85 per ton. Calculating the usual amount for depreciation, 6 per cent., we get 51 cents a ton for this item. It is stated that mining costs in the principal mines are about $2.25 per ton.

The entire minimum cost of operating at Guanajuato may be tabulated as follows:

Mining	$2.25
Milling	1.60
Amortization	0.85
Depreciation	0.51
Total	$5.21

With an extraction of 85 per cent. these costs mean that the minimum grade ore that can be handled must have an assay value of some $6.50 per ton, which means in round numbers some 10 oz. in silver and $1 per ton in gold.

The higher grade ores, as in other districts, are more costly. The Pinguico mine in 1908 produced 82,750 tons of ore worth $1,088,000 or $13.16 a ton. The profits were $425,705, or a trifle over $5.14 a ton, so that the total costs were $8.02. The extraction is stated to be 85.56 per cent. of the gross value of the ore. In this case, therefore, the minimum value that will stand working is in the neighborhood of $10 a ton.

It seems that up to the present the profits of the Guanajuato mines have been very moderate. Pinguico, just mentioned, is probably the most prosperous. It produced silver in 1908 at an approximate cost of 35 cents an ounce. It is probable that for the district at large the present cost of silver is approximately 50 cents an ounce against 27 cents at Cobalt.

Note in 1919.—The effort to renew operations on a large scale at Guanajuato did not prove very successful.

Early Output of Tombstone

It seems that three authorities are available on the first stage of Tombstone's mining history: W. P. Blake, a well-known mining engineer, who seems to have been familiar with the camp in its earliest days, having written a paper on it for the Transactions of American Institute of Mining Engineers (Vol. X, 1882), and later a report for the Development Company of America, dated July 28, 1902; John A. Church, who was another mining engineer of high standing, General Manager of the Tombstone Mill & Mining Company in its early days, later acting as consulting engineer for the Tombstone Consolidated Mines Company, and who wrote an article on the district for the Transactions of American Institute of Mining Engineers, 1903; and W. F. Staunton, who was superintendent of the Tombstone Mill & Mining Company for eleven years up to the time of its closing down in 1894, and who wrote two reports on the district: one in 1894, and the second June 29, 1901, addressed to Mr. Geo. A. Beaton, of New York. It is evident from the remarks in these various papers that these gentlemen were well acquainted with one another. Blake's statistics, other than those given in his first paper in the Transactions, quotes Mr. Staunton and Mr. Church as authorities and gives statistics from the records of the Tombstone Mill & Mining Company, with which both these men had been connected. I cite this to show that the figures given by these authorities all appear to have come from the same source, and that their latest reports were written about the same time and cover about the same ground. No two of the three, however, give exactly the same details, although they agree pretty well on the total production. From them all I get the following figures:

Church says the entire yield of Tombstone up to 1902 was:

Gold 163,000 ounces, Silver 21,500,000 ounces, Lead 5,000 tons.
He assumes that to get the gross content of the ore it would be fair to add about 15 per cent. to this.

He also states that the output of the Tombstone Mill & Mining Company from June, 1879 to December, 1893, which I believe covers almost its entire history, was:

Gold 37,676 ounces, Silver 6,707,158 ounces.

From Blake's report I get the following figures and deductions for the same company.

From June, 1879 to March, 1884:

	Tons	Gold, oz.	Silver, oz.	Lead, tons	Average silver, ounces
	91,086	10,931	3,459,554	777	38

From March, 1888 to June 30, 1893, all shipped to smelters:

	Tons	Gold, oz.	Silver, oz.	Lead, tons	Average silver, ounces
1889	3,885	3,009	187,023	76	
1890	3,232	2,166	177,260	82	
1891	3,891	3,339	239,801	293	
1892	7,028	4,207	460,506	631	
1893	8,452	2,950	392,165	603	
	26,518	15,671	1,456,756	1,685	55

By adding the detailed productions together and subtracting them from the total output given by Church, we may deduce that from March, 1884, to March, 1888, four years for which there are not details, there must have been produced by the Tombstone Mill & Mining Company about—

Tons	Gold, oz.	Silver, oz.	Lead, tons	Average silver, ounces
70,000	11,074	1,790,840		25

The tonnage for these years is not stated but as at the end of the first period milling was going on regularly at the rate of about 17,500 tons a year, we may guess the tonnage to be about 70,000.

These figures are for the Lucky Cuss, West Side-Sulphuret, Northwest, Toughnut and Charleston Mines.

It is very noticeable that in the five last years the tonnage had dwindled but that the grade had risen. One may surmise that about 1887 it had been decided not to attempt to keep the mill going but to ship such ore as would pay to the smelters. To sum up, we may suppose that the total tonnage of this concern was somewhere around 187,000, and that the grand average of the ore was about $4 gold and 35 ounces silver. Under the prices ruling in those times the gross receipts were about $8,000,000 or no less than $43 a ton. But the dividends paid were only $1,500,000 or $8 a ton. It is stated that total profits were about $2,000,000, the difference having been paid for additional property. Even at this, the profits were only $11 a ton and the costs $32 a ton. Mr. Staunton states that at the beginning the cost of mining, milling, freight to mill, etc., was $27.42 a ton and the lowest ever obtained was $12.90. We might suppose from this that the cost averaged about $20, but this included only the "practical" cost of operating and no doubt did not include such items as freight and treatment on ores shipped, or general expenses in which there may have been considerable for litigation. Although $12 a ton seems an enormous amount for such costs, the sum total $2,200,000 is not incredible when we consider that it was spread over a period of 15 years. It would have averaged about $12,000 a month. At any rate, such were the dividends earned and such must have been the costs, no matter how they are to be explained.

The other dividend-paying mines of the district were the Contention

and Grand Central, both working on one vein. They are vaguely credited with a total of $4,750,000 in dividends. The gross output of these mines is given at about $13,000,000. The total tonnage is unknown but in 1882 the Contention mined 25,017 tons from which bullion worth $1,676,705.96 was realized, an average saving of $67 a ton. Since both these mines came to an abrupt end about 1886 and since the milling capacity does not seem to have been greater than 90 tons a day for either mine, it is hard to see from the figures how the total tonnage produced could have risen even as high as 300,000 and it is a fair inference that the average ore produced from those mines certainly averaged over $40 and probably over $50 a ton. It is reported that the total output of the Contention up to 1887 was $6,034,000. Of this $4,380,000 were produced before 1883, leaving only $1,700,000 for the production of the four succeeding years. From these facts, if they are facts, we may draw several inferences:

1. More than three-quarters of the value from the Contention mine came from ore yielding around $70 a ton.

2. If the remaining ore ran only $30 a ton, the grand average must have been over $50.

3. According to these figures, the total tonnage would be not over 120,000, the dividends paid (total $2,750,000) would be about $23, and the costs $27 a ton.

4. The mine declined abruptly years before the water situation became acute, therefore not from encountering the water, but because a body of rich ore came to an end. Mr. Staunton says the pumps were stopped at the time of the fire which destroyed the Grand Central works, May, 1886; therefore, in three years and five months following 1883 the total production was no greater than it had been in that single year.

5. The Grand Central mine came to a practical end about 1886, having produced in four years and four months somewhere around $6,000,000 from a total tonnage probably not exceeding 130,000, thus averaging probably $45 or more per ton.

6. Out of a total tonnage of 150,000, more or less, its dividends were only $2,000,000, or less than $14 a ton, and its total costs must have been more than $30 a ton.

7. That in both mines such costs could only have been caused by mining small bodies of high-grade ore which could be opened up only by an enormous amount of development work.

It seems to me we may fairly believe that the broad facts in regard to the few prosperous years of Tombstone are that the three properties just mentioned produced altogether about $21,000,000 gross and $6,250,000 in dividends—all the dividends paid in the district; that their gross output was over 80 per cent. of that of the whole district; that

their total tonnage was around 460,000; that the average grade of the ore under prices then ruling was between $45 and $50 a ton, averaging nearly $6 in gold and $40 in silver (about 38 ounces); that if the same ore had been mined under the average prices of the past 15 years, say 57 cents an ounce for silver, the average grade of the ore would have been only $27.60 per ton, and that under the costs actually obtained by those companies there would have been no profits at all.

Tombstone Consolidated Mines Company

It appears further that while the prosperous days of the camp ended about 1886, several of the mines, like the Tombstone Mill & Mining Company, continued operating on a reduced scale until the panic of 1893. The latter company finally closed down in 1894. During the period of general low prices, 1893 to 1899, the camp was probably almost deserted. A revival of optimism about the district accompanied the industrial boom of 1899 and the years following. The properties mentioned above, perhaps together with some others, were consolidated into the Tombstone Consolidated Mines Company and a comprehensive scheme of exploration was undertaken, directly mainly toward pursuing the orebodies below the water level. Messrs. Blake, Church and Staunton were employed as consulting engineers, so that full advantage was taken of the long experience of those gentlemen with the earlier and more prosperous days. It may be well to mention that it was part of the theory of the new company that large economies would result from a combined ownership.

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